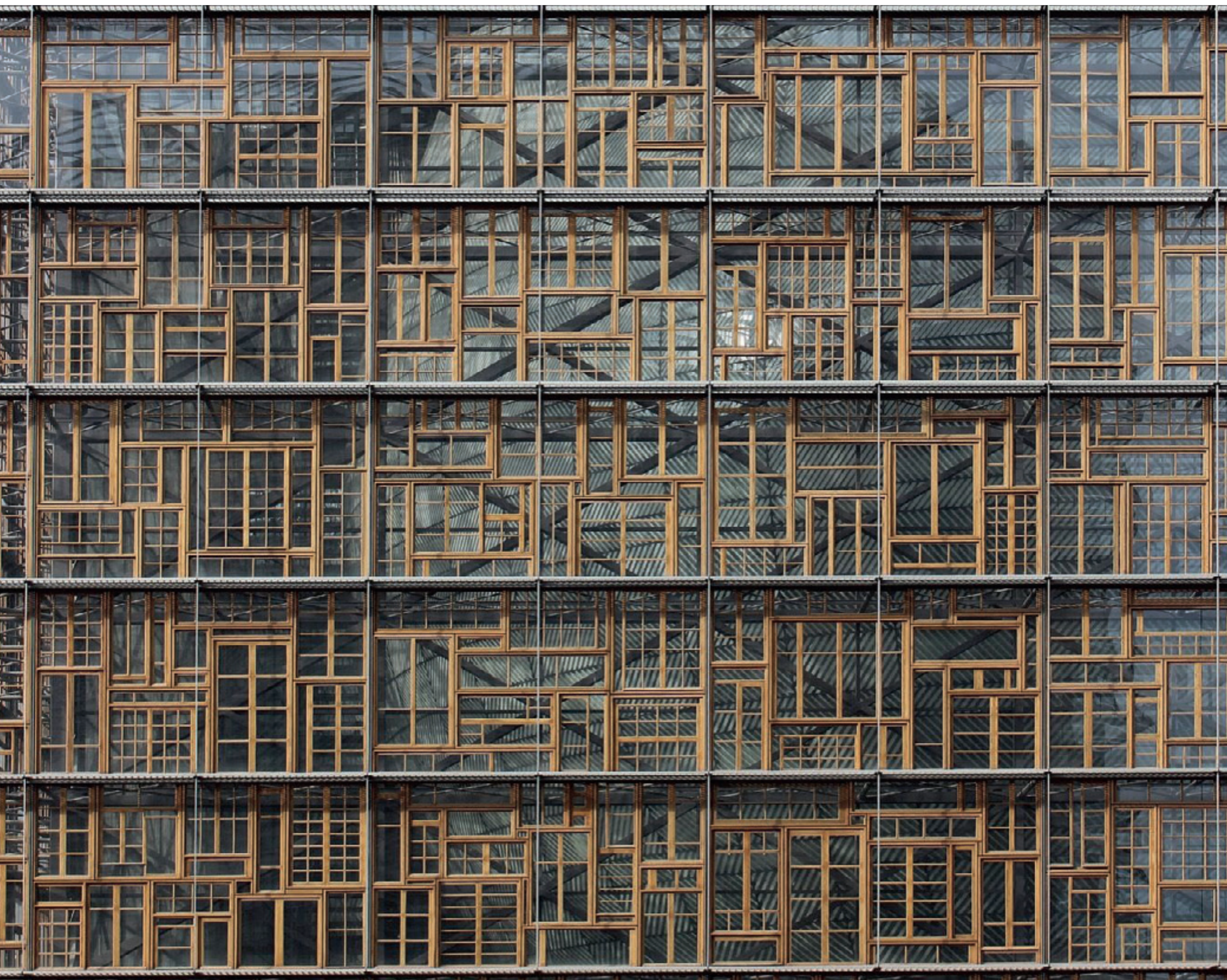
REUSE

CHALLENGES TO SALVAGE
BUILDING COMPONENTS



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ABSTRACT

The work presented herein is based on the challenges and changes that human society is facing, notably the transition towards a sustainable approach to design, production and consumption. Such challenges have become an urgent matter due to the global increase in consumption leaded by industrialization advancements and globalization. Right now the built environment accounts for a large share of the global CO2 emissions and energy consumption throughout Earth, with an increasing demand for building materials each year and ever decreasing natural resources. At the end of their lives buildings are often demolished, thus becoming a source of waste.

What if we could use this waste for future new builds? Among the many processing techniques available today, recycling and reuse are progressively giving a second life to our waste. Construction materials should not be considered as waste that needs to be evacuated anymore but as a resource to be valued and preserved. This approach on materials could generate new insights on architecture, construction; leading potentially to a fundamental change concerning the concepts of ‘raw materials’ and ‘waste’.

The aim of this thesis is to identify and sort building components and materials that come into consideration for reuse in buildings in European cities that are going to be demolished in the next few years.

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INTRODUCTION

TOWARDS A NEW ARCHITECTURAL APPROACH: REINVENTING THE WAY EXISTENT MATERIALS CAN BE REUSED IN OUR CITIES

Nowadays, the building industry faces a number of critics about its environmental impact due to its energy consumption, its need for virgin resources and its production of waste. A depletion of natural resources, an accumulation of waste and an acceleration in the production of greenhouse gas emissions, having an impact on global warming, have been noticed in the first part of the 21st century. Constructions have a big influence on these changes. As architect Elma Durmisevic outlines: « In Europe the building industry accounts for 38 percent of the total waste production, 40 percent of the CO2 emissions and 50 percent of all natural resources used within the building sector »[1]. Considering the pattern of demographic increase, the demand for new buildings will go up in the next years, generating even more waste and demand for natural resources.

The awareness about ecological and energetic problematics in our modern time encourages people working in the building activity to find new ways to prevent the growing consumption of resources. Actors involved in this process should use their creativity and imagination to find solutions to make this industry more sustainable. This joins the concept of 'circular economy' based on the idea that it is possible to « maintain and promote existing resources »[2] by reducing the environmental impacts of extraction, production and treatment of materials. In the building industry, different ideas try to tackle this problem. Some aim to find new approaches in the design of future buildings, such as 'design for adaptability' or 'design for disassembly'. This is an approach where future buildings should

1 Elma Durmisevic, *Systemic review on reuse potential of building elements, components and systems-comprehensive framework for assessing reuse potential of building elements*, International HISER conference, june 2017, Delft, p. 275

2 Michaël Ghyoot, *Objectif réemploi: pistes d'action pour développer le secteur du réemploi des éléments de construction en Région de Bruxelles-Capitale*, août 2017, p.7, translation by Charlotte Astaes

be planned in such a way that once they are not used anymore, the various components can easily be taken apart and find a secondary use. This essay tries to cast light on another approach which aims to recover materials already present in our cities. This is known as “reuse”. In architecture, it means that building components or materials are recovered from buildings with the least amount of damages possible. The integrity of the elements is preserved and there is, in most cases, no need for heavy operations on them, but they can still be subject to some small repairs and cleaning. They are then implemented into a new design and will have the same use as before or they will be adapted to make it possible to use them in a different way. Sometimes, reuse can also be mentioned when domestic waste materials are used again as materials in the construction sector, such as bottles or cans used to construct walls. This type of reuse will not be addressed in this essay. It is also important to distinguish reuse from recycling. The latter involves a deep transformation of the construction elements who are crushed and transformed by manufacturing processes to produce new products before being used again.

The elements are recovered from the buildings present in our cities through the deconstruction process. The Belgian architecture studio Rotor wrote about this approach, and said: « that instead of putting everything indiscriminately on the ground and throwing the rubble into unexploited ground, the different layers of the buildings are removed successively to gradually reach the bare skeleton »[3]. Although it seems fairly straightforward, the practical implementation of deconstruction and reuse faces many obstacles. Today, only a small amount of building components and materials are reused due to a lack of information about salvaged parts and general difficulties regarding their recovery.

To be able to reuse, various activities are involved such as the identification of reusable elements in buildings, the dismantling, transportation, storing, refurbishment, documentation, selling and many more. In this essay, most of these activities will be mentioned but the focus will be on the criteria that have an impact on the identification and assessment of the items that could possibly be reused.

3 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.61, translation by Charlotte Astaes

This essay is separated into three different parts.

The first chapter aims to highlight the circumstances in which reuse came back to the forefront of discussions a well as other notions related to reuse in the context of a sustainable development. First the concepts of ‘circular economy’ and ‘urban mining’ will be introduced. After that, different types of reuses are analysed: one where buildings are kept on site and others where either the whole or some the parts have to be translocated to a different location. Finally, the topic of deconstruction and the benefits of this approach will also be addressed.

The second chapter focuses on the criteria that influence the reusability of a component. Today, less than 10 percent of buildings is reusable. This is only a very small portion and this chapter tries to understand the criteria that are used to assess which materials have the potential of being reused, and so, should be salvaged. They involve factors relating to construction techniques, contamination by hazardous materials, assembling techniques, the quality of the components, strict building standards and regulations, concepts of beauty, and finally economics. All of these criteria do overlap at some point but they are separated into different topics. For each of them, a description of what the criterion involves and an explanation supported by a case study will be given.

The third chapter attempts to set up a methodology. Accompanied by a physical box, this section of the essay will try to define the questions one should ask him/herself when confronted to a building that is going to be demolished and trying to have the most sustainable attitude towards this demolition.

I

REUSE IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

This chapter aims to highlight the circumstances in which reuse came back to the forefront of discussions a well as other notions related to reuse in the context of a sustainable development. First the concepts of ‘circular economy’ and ‘urban mining’ will be introduced. After that, different types of reuses are analysed: one where buildings are kept on site and others where either the whole or some the parts have to be translocated to a different location. Finally, the topic of deconstruction and the benefits of this approach will also be addressed

THE CIRCULAR ECONOMY

A NEW ECONOMIC MODEL

Today, we live in a linear based economy model build on « 'take-make-dispose' processes »[1], meaning that almost all the products we are using in our everyday life are made from extracted raw materials found in nature and which have been transformed into goods that we then consume. Once we have used them, we do not see any need for these products anymore and throw them away. To our eyes, they do not have any value anymore and they will be incinerated are put into landfills, hidden away from our vision. As pointed out in the book *Matière grise*: « This way of living creates a crisis with two sides: on the one hand there is a depletion of the existing natural resources and on the other hand, there exists an accumulation of waste. It is a planetary excavation-backfill where huge holes are dug and huge piles are made »[2].

This linear economy also dominates the building industry where raw materials are extracted from mines, quarries and forests before being transported to large industries to be processed into building components or materials that finally will be assembled in order to create buildings. Once used, because of decay or obsolescence, these constructions are demolished and even if a part of the construction is sorted and recycled, most of the demolition debris is disposed into landfills.

Since the 1970s, with the oil crisis and other reasons, we assist to a general awareness of the physical constraints and start to understand the consequences of this linear model of our economy. For instance, a team of researchers called 'The Club of Rome' published in 1972 a report called *Limits to Growth in which*

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1 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p.22

2 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.37, translation by Charlotte Astaes

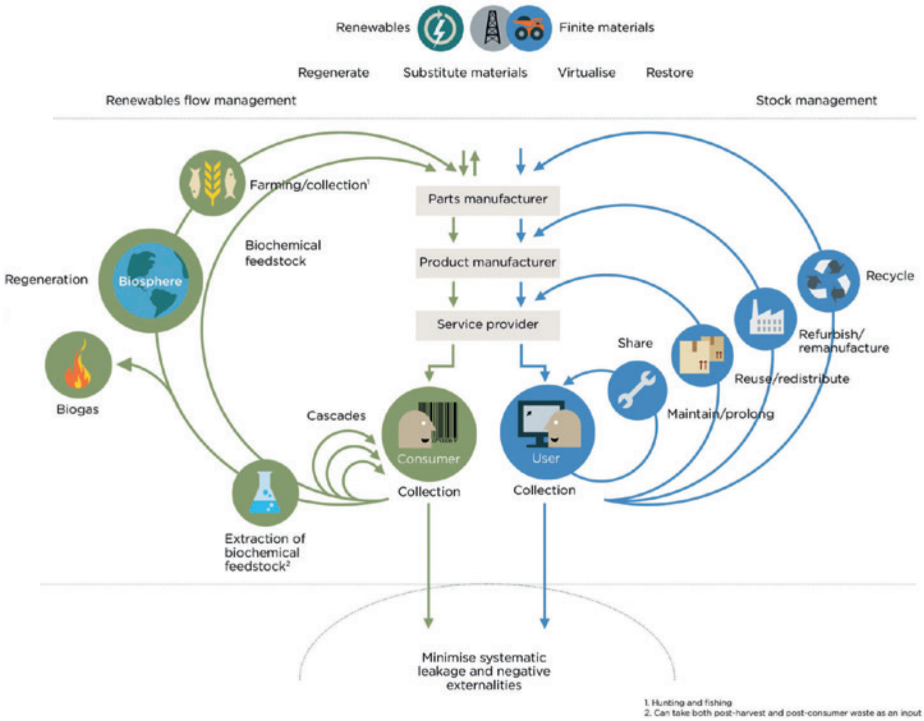

Figure 1. Drawing by Braungart & McDonou, explanation of the circular economy

« they concluded that the current economic production model was not sustainable due to increasing demand for raw materials and worldwide accumulation of waste »[3]. In other words, the growing population and the increase of their consumption will lead to problems in the future if nothing changes in our way of living.

During the same period, collectives were born in the United-States for whom these questions of resource scarcity, waste production and general pollution became central questions in their architecture. They wanted to explore a lifestyle and new types of constructions that would be more economical and less harmful form an ecological point of view by being energetically independent. One example is the American architect Michael Reynolds and his Earthships built in Taos, New Mexico. These are self-sufficient

3 Arcadis, *The circular economy: what is it and what does it mean for you?*, arcadis briefing paper, p.1

Figure 2. Photography of Mike Reynolds standing in front of his first “Earthship”

shelters constructed from everyday waste such as stacked tires, glass bottles and assembled beer cans in a way to form bricks. The tires were filled with earth and this permits to obtains a high quality thermal mass and it regulates the inside temperature of the buildings. These dwellings are autonomous in terms of energy by using solar panels and water by collecting and treating it themselves.

It is in this same context that Walter Stahel, a Swiss architect and industrial analyst, started to talk of an ‘economy in loops’[4], also known today as circular economy. This alternative economical model is trying to change our way of producing goods. In this approach, the lifecycle of the products should be extended by reusing them. This is a strategy that would prevent waste being produced in big quantities and would also reduce environment deterioration. He was also one of the first to bring up the concept of the 3R’s. This stands for the words ‘Reuse, Repair and Remanufacture’ for which he « argued that smaller closed loops, such as reuse and renovation, are more beneficial than recycling as they require less input of new resources »[5]. The terms of the concept of the 3R’s have changed a bit through time and today it stands for ‘Reduce, Reuse and Recycle’.

These terms can be found again in the zero waste hierarchy

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4 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p. 23

5 *Ibidem*

often portrayed as a pyramid. It « classifies and evaluates methods of dealing with waste according to energy consumption and energy loss: the less material has to be processed and the less energy required to do so, the better »[6]. In other words, some actions should be prioritized in comparison to others with the intention to conserve discarded resources and protect the environment. At the top of this hierarchy, we find reduce, meaning that the amount of waste should be minimized. The initial use should be avoided when possible and we should try not to buy or use things that we do not need. Then comes reuse where items are used again in a new context. The lifecycle of the product is stretched out through repairs and cleaning. After that comes recycling, which means processing and transforming materials in order to create new products. Two steps are often added in the pyramid in addition to the 3R's. The first one is Energy recovery where the elements are regained and converted in order to produce some energy such as heat, light and electricity for example through combustion. The resource is destroyed but it is still better seen than the last step of the hierarchy, which is Disposal. The products are put into landfills and incinerated.

The concept of circular economy has been evolving since the 1970s and more recently, the Ellen MacArthur foundation is

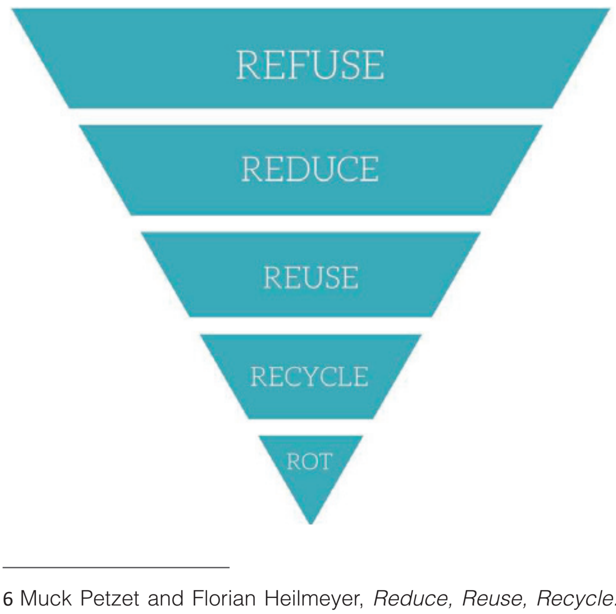

Figure 3. Diagram of the zero waste hierarchy

6 Muck Petzet and Florian Heilmeyer, *Reduce, Reuse, Recycle: architecture as resource*, Hatje Cantz Verlag, 2012 , p49

considered to be one of the pioneers when it comes to this new economic model. The definition they give can be found in the book *Resource Salvation: the architecture of reuse* and is: « The circular economy is one that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. This new economic model seeks to ultimately decouple global economic development from finite resource consumption. It enables key objectives such as generating economic growth, creating jobs, and reducing environmental impacts, including carbon emissions »[7]

Applying this definition and the zero waste hierarchy to the building industry means that we should re-examine the materials and elements composing a building focusing on long-term value in such a way that buildings would become adaptable to new uses and durable. In this way of thinking, keeping the building in its whole, continuing its use and avoiding demolition would be the most sustainable thing to do. The smallest interventions on the building become the best. When this is not possible, the building components and materials should be reused as much as possible without being transformed, but they could undertake a small refurbishment such as cleaning and light repair. This means that we should focus on the quality of the materials and components in order to make long lasting products. The next step in the pyramid would be to recycle the materials that come from the construction in order to produce new materials. Only if none of these steps is possible, the components should be incinerated or put into landfills. In such a system, building new constructions would require less energy, would produce fewer carbon emissions and the demand for raw materials would be reduced. This new economic model will drive innovation. New creative and imaginative methods will have to be implemented to be able to reuse elements that already have been used in another context.

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7 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p.23

URBAN MINING

THE CITY SEEN AS AN 'URBAN MINE' FULL OF POTENTIAL

In this concept of reuse, it is necessary to understand where the resources come from. A city is a heterogeneous and diverse place that has evolved over time, where buildings have been accumulating. This idea is underlined in the article of the Swiss historian André Corboz that « qualified the territory of a 'palimpsest', bearing traces of his successive occupations »[1]. The territory is defined by all the buildings composing it.

The city, with all its layers, is a place that should be looked at and carefully analysed. We should try to have a look at all it has to offer as there is a strong potential to discover hidden gems in what already exists. It is in this framework that the 'mining metaphor' is often used. The city is then portrayed as an 'urban mine' in which building materials should be extracted and exploited. The metaphor of the mine offers an image where the city becomes a place with a large stock of hidden resources which can be discovered, retrieved and used again. It should ceased to only be seen as a place where waste is made and build-up. Urban mining can also be defined as a concept that « recognizes the embodied value of this stock and proposes the systematic reuse of these anthropogenic materials, which are already present and underused within urban environments »[2]. For a very long time, we have been excavated and extracting resources from the ground but now we should start finding the materials above the ground, in our existing built environment where resources are compiled under the form of materials or building components. The urban fabric we live in thus becomes a place to obtain valuable elements to which we can give a second life.

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1 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.89, translation by Charlotte Astaes

2 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p.47

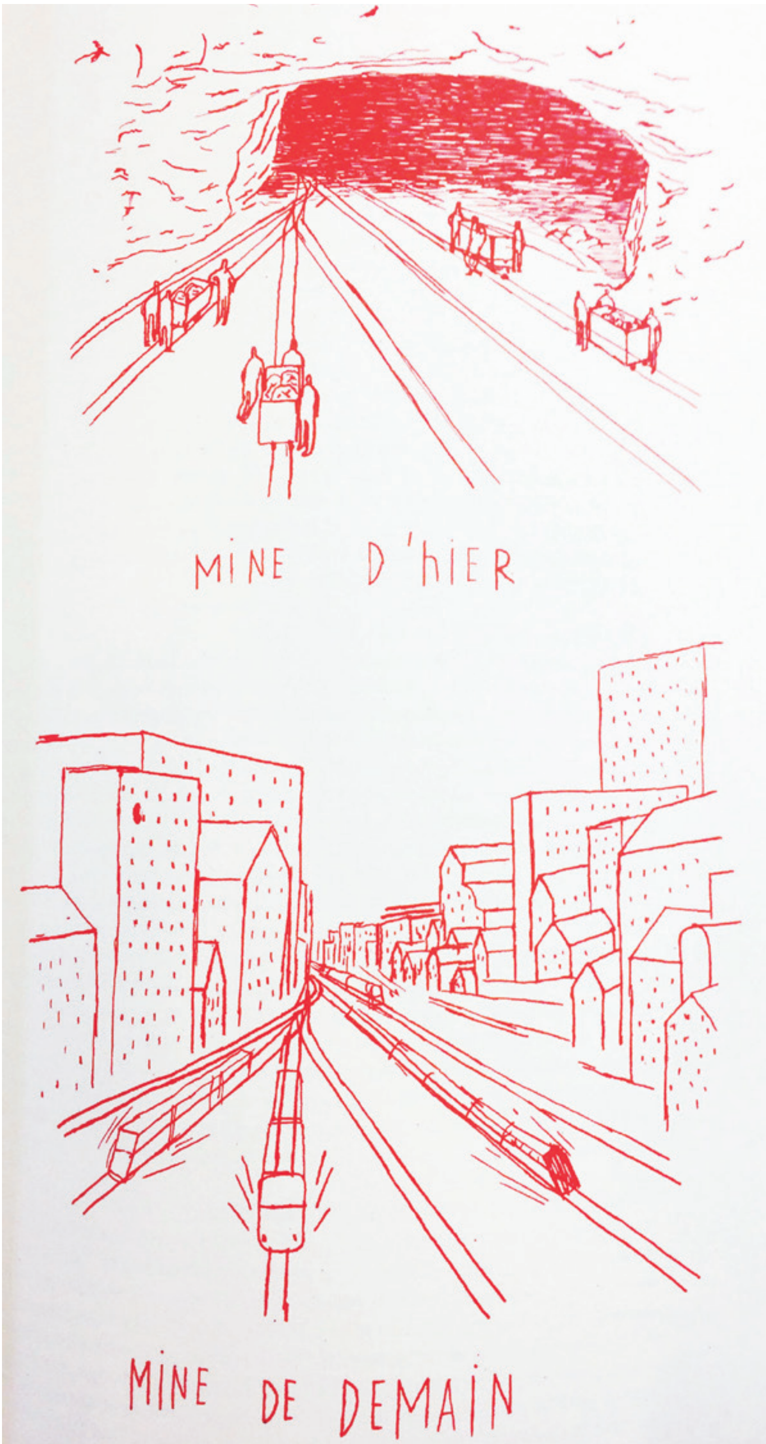

Figure 4. Drawing by Bonnefrite, illustration of the urban mining concept

In our culture, we assume that buildings are here to stay, that they will last a long time and « most architects hope that their creations will last and become permanent and unaltered »[3]. They do not imagine their designs as being disposable and possibly destroyed just after a few years, « yet cultural, technical and economic undercurrents lead to the fact that our buildings often become waste sooner than expected »[4]. In most cases, once the building has been used, it rarely has a further life and it will probably be demolished soon afterwards under the pretext that this building is no longer adapted to the current demand. We observe that after their first purpose, buildings, become in many cases obsolete. It means that they are not longer seen as being useful. They can also be seen as outmoded and coming from another time, not being able to accommodate contemporary habits and not being appreciated by the general population. Obsolescence, from its latin origin mean 'grown old, worn-out'[5] but the term is actually connected to a variety of different reasons. The building can be physically in a bad state: the materials have aged and the maintenance becomes difficult and expensive. Sometimes, if can even be dangerous to keep on using these types of constructions because of the deterioration of the materials. Some parts of the building can also be damaged because of a fire or an inundation. Economical reasons can also have an impact. For example, when an area is being redeveloped, all the buildings on site are bought and demolished in order to construct the new project. Furthermore, many obsolete buildings come from depopulation; people leave their homes based in smaller cities in order to go live in bigger cities. Other factors that make a building outmoded can come from environmental, political and functional reasons.

In most cases, once the building has been qualified as obsolete, it will probably be demolished and replaced. The urbanism of the 21st century in European cities obeys to the principle of the '*tabula rasa*' where everything is erased and reconstructed from scratch. This way, space is made in order to create the new. By

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3 *Ibidem*, p. 14

4 *Ibidem*, p. 14-15

5 Oxford University Press, Definition of obsolete in *Oxford Dictionaries*, (s.d.), retrieved December 2, 2018 from https://en.oxforddictionaries.com/definition/obsolete

Figure 5. Photography of a building's demolition

following this approach, much of the patrimony has disappeared and has been lost forever. Since the industrial revolution and with technical advances, we tend to eliminate the former layers of the territory without leaving any traces of it. Despite the fact that the profession has changed over the past twenty years and that big steel ball demolishing the buildings are now gone, the construction and demolition sites are still filled with powerful machines. Although demolishers are paying more attention to the sorting of materials, separating them in order to recycle most of it, there is still much improvement needed. For example, the excavator has been described as « the real Swiss army knife of demolition »[6] because the arm of this machine can welcome a multitude of tools, such as « scissors to shear scraps, jaws for gnawing concrete beams, jackhammers, ect »[7]. This way of doing demolishes many viable constructions and transforms the buildings into rubble. This produces an enormous amount of waste, unusable, ready to be disposed of in landfills and all the grey energy stored in these buildings is « being squandered thoughtlessly »[8].

6 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.33, translation by Charlotte Astaes

7 *Ibidem*

8 Muck Petzet and Florian Heilmeyer, *Reduce, Reuse, Recycle: architecture as resource*, Hatje Cantz Verlag, 2012, p.9

These buildings « are being demolished because of a mix of ignorance, lack of imagination and intellectual laziness »[9] but we are trying to find solutions that do not oblige builders or architects to start all over again after the *tabula rasa*. In cities around the world, we are starting to see buildings that were left into a state of decay and which were going to be swiped away actually be used as a stock of potentially valuable materials. These buildings still have some qualities and they can be used in a new context. This is underlined in the book *Resource Salvation*: « there is increasing recognition that a building at the end of its life is an asset to be valued and that innovation and imaginative design can offer new opportunities for using discarded materials and components as valuable parts of buildings »[10]. Instead of being demolished, a building without a new purpose should attentively be looked at, and the discarded structure should also become part of the mining process. Once this has been acknowledged, different strategies can be put into place in this context of urban mining. The buildings can be kept in their totality, keeping the structure and spatial arrangements. And, when this is not possible, parts, components, and materials can be reused on site or elsewhere in a new project. In the future, we will see a decrease in the need for new buildings and the architect will have to deal more and more with the existing structures. All type of constructions will have to be looked at and not only the ones created by famous architects or the ones that have a patrimonial value.

Keeping the found building in its entirety would be one of the most sustainable actions that could be done. First, we should try to improve what is already there and renew the existing infrastructure, adapt it to our needs. Of course, not everything can be recovered and sometimes demolition does not make any sense. It can even be dangerous in some cases if the construction is poorly made and some buildings really do not have any positive qualities. Demolition should not be forbidden but it should certainly be more carefully considered. Nevertheless, buildings are a complicated assemblage of many different layers. It does not mean that all the parts constituting

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9 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.73, translation by Charlotte Astaes

10 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p.1

the construction have lost their value and should become waste. Every architecture is different and it has to be assessed each time. André Kempe, from the Dutch office Atelier Kempe Thill, says in the book *Reduce, Reuse, Recycle* that « The decision about whether it makes more sense to demolish or renovate must be considered anew each time, on a case-by-case basis »[11]. It is important to evaluate the construction and its spaces to determine if some form of reuse can be established.

The value of the materials that are taken from cities should definitely be preserved, in the same way that virgin resources are extracted from mines. New methods have to be implemented replacing the Caterpillar machine destroying everything on its way. One possible method is dismantling, this is a slow and rigorous process of deconstruction, asking for specific knowledge and aptitude to maintain the value and usefulness of elements because they are not destroyed by the way they have been removed.

11 Muck Petzet and Florian Heilmeyer, *Reduce, Reuse, Recycle: architecture as resource*, Hatje Cantz Verlag, 2012 , p.98

ADAPTIVE REUSE

KEEPING AND PRESERVING THE BUILDING ON SITE

To allow a prolongation of the life expectancy of a building, it can be kept and preserved on the site it has been built on. This would ask for a lesser amount of interventions and energy and it would directly permit to conserve much more than if the infrastructure would be deconstructed. Only components and materials that have not been damaged can be reused and nowadays this does not represent a big amount of the total construction. In comparison to deconstruction, keeping the building in its whole and repairing or adapting it to a new use allows to preserve much more resources. This is a sustainable choice because « this will avoid the creation of much demolition waste that will have to be dealt with, as well as the need for large quantities of new building materials »[1]. By avoiding the manufacturing of new elements, the conservation enables to reduce the current carbon emissions in the atmosphere related to the building industry and the construction of new buildings. So, instead of demolishing or deconstructing our urban fabric, we should first of all try to improve what is already there and renew it. This way, the lifecycle of a building is affected and expanded; its death by bulldozers is therefore delayed.

This approach of preserving buildings and reconvert them is not new. Nowadays, it is relatively common to do so with historic buildings, seen as having a cultural value. The content is considered to be worthy enough to be passed on to the future generations. However, architects should not only look at these types of buildings but should take an interest in everything else that constitutes the city: including the anonymous architecture, industrial infrastructures and ordinary buildings. Today « such buildings are potentially

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1 Bill Adis, *Building with reclaimed components and materials: a design handbook for reuse and recycling*, Earthscan, 2006, p.14

endangered [...] (and) all too often dismissed as worthless »[2]. In most cases their value is not perceived. The hidden qualities and potential in these type of constructions have to be discovered and exploited.

The existing structure has to be carefully looked at and evaluated each time. Some buildings do not have the ability to be altered in a way to welcome a new function. However, a lot of constructions are being torn down without even considering the idea that they could be reused by staying in place. As German architect Arno Brandlhuber points out: « It's pointless to tear down something that could just as well continue to serve as the basis for something else. Of course it's necessary to carefully examine what can still be done with the existing building »[3]. Any type of work on existing infrastructures starts by understanding the building and its qualities. It has to be evaluated to be able to assess what kind of alteration should be done. The idea is to regenerate the building and adding the lost or lacking qualities. Once the valuation has been done, a new project can be developed.

When architects work with existing architecture, they are confronted to different aspects. They have in front of them a concept, materials, spaces, and design decisions that were chosen and implemented by other architects. They have to understand and interpret what they see and make decisions on what has to be done in order to develop a new project. Two different stories get interweaved. This can be seen as an interesting challenge to some people because of the flexibility, imagination and creativity required to be able to work on these type of projects. German architect Muck Petzet outlines this idea by saying: « such existing stock [...] can provoke ideas for new solutions and scope for creativity »[4].

There are several ways to deal with the original building. The main idea is that the general shape of the construction is kept: the structure, the foundations and as much of the envelope stay on place. Nevertheless, changes completed on the construction will differ between a building and another, such as underlined by

2 Muck Petzet and Florian Heilmeyer, *Reduce, Reuse, Recycle: architecture as resource*, Hatje Cantz Verlag, 2012 , p.11

3 *Ibidem,* p.82

4 *Ibidem,* p.11

Muck Petzet: « the required change has to be determined anew with each task [...] The extent of the intervention may range from repair to complete restructuring or reshaping »[5]. This means that there is a large scope of possible interventions. It can be very minimal adjustments, only involving the maintenance of the building, such as cleaning, and repairing small damages. In this case, only the absolute essential is replaced or renovated in order to enhance the building's qualities. The building is kept as close as possible to its initial existence and in most cases also maintains its primary function. Bigger transformations can occur when the building is renovated or converted. The construction can be striped down to its bare structure in order to renew its interior organisation. This way, the spaces inside are left empty and can be adapted to the new use. The rooms inside may have to be reorganised implying that some elements will have to be demolished and rebuild to make this possible. The outer appearance would normally remain relatively the same. The image of the building can be changed when the skin is replaced. This can happen if the building's façade and general impression is outdated or to make sure that the envelope is up to standards. More massive alterations can occur when a building is expanded or reduced. The appearance of the building changes in these cases and the footprint of the building can also be modified. Addition of usable space can be done by raising the building with a couple of new floors, it can be lengthened, enlarged or a new structure can be attached to the initial one. Some buildings need less surface, meaning that the total surface of the building will be reduced. By subtraction, some parts can be removed or the whole can be lowered down by taking away some levels.

The question then is how the new and the old are connected, a balance has to be found. On the one hand, there can be an obvious distinction between the two parts. The opposition can be exaggerated. A contrast can be formed in a way to differentiate each new layer that came on top of the original as distinctly as possible because, as Sonja Nagel outlines in the book *Reduce, Reuse, Recycle*, « seams [...] can spawn a depth of information in which the development of the architecture becomes more intelligible »[6].

5 *Ibidem,* p.10

6 *Ibidem,* p.164

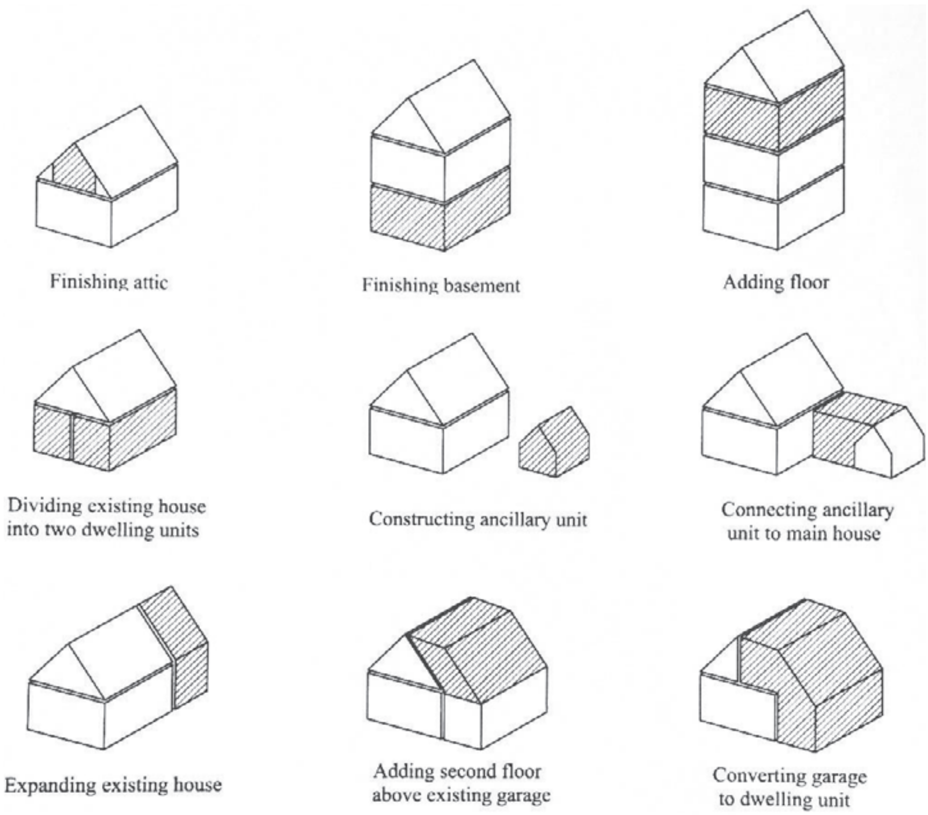

Figure 6. Drawing by Braungart & McDonou,
explanation of the circular economy

On the other hand, there can be no distinction between the old part and the new changes. In some cases, the intervention can be hardly distinguished from the pre-existing condition and the alterations become almost invisible. A continuity can be achieved between the two, there are interwoven in a way to create one whole.

Their exist examples where the buildings are altered and preserved but in a lot of cases, this is not done so easily because they were not designed in a way where the use would be modified after some years. The architect and engineer, Raphaël Ménard describes them as « typological monsters, unable to become anything other than themselves »[7]. An interest is given in buildings

7 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.163, translation by Charlotte Astaes

that are being built now or in the next years to make them adaptable. A possible plan B is proposed for the structure and how it could be transformed years later. This way, the project can more easily welcome a new program. The monsters would be replaced by « capable skeletons »[8]. This is what the French architects Lacaton and Vassal have done in their project for the architecture school of Nantes that was designed with the idea that it could be changed in a few years if needed. This school is built with larger dimensions than necessary. The concrete structure has been overdimensioned and the classrooms are made of double height ceilings. This would enable to add secondary slabs in between the very high spaces. The school thus can be easily transformed to a new function, for example, to accommodate housing.

Designing adaptable buildings and working on what already exist will probably become important parts of the architectural work in the future. When it is not possible to keep the construction in its entirety, other ways exist to translocate information in various forms of the original building.

8 *Ibidem*

TRANSLOCATION

TAKING AN ELEMENT FROM THE ORIGINAL BUILDING AND MOVING IT TO A NEW LOCATION

In some cases, reusing the building in situ is not possible. Nevertheless, there are other ways that enable to keep the building's materials, information or its image instead of demolishing it, making all the qualities of the construction disappear into rubble. It is possible to take something from the original building and put it somewhere else, to a new location. There are many ways of doing this, some where the building still stays intact and other where only parts or a memory is kept and translocated. Some possible transfers will be discussed here. In one approach, most of the building is conserved to meet new propositions and parts are taken and used somewhere else. In another approach, the physical elements of a project completely disappear and only an idea or a memory is reused.

Firstly, the entire building can be moved to another location. In this case, it can be done in two different ways. On one hand, the construction can be dismantled, the parts are then brought to the new location and the building is then re-erected. This is mostly done for temporary structures where the assembling techniques are thought of to be easily reversible. It can also happen to more permanent buildings. For example with old timber-framed buildings that have reversible jointing methods or brick walls assembled with lime mortar can be dismantled and rebuilt. On the other hand, the building in its entirety can be transported somewhere else, without any alterations. This is normally done by raising the structure from the ground and putting it on a structure with wheels or on rails that will help move the whole. For example, the Nathaniel Lieb house, built by the American architect Robert Venturi was planned to be demolished. Instead, it was relocated from Long Beach Island to Glen Cove in New York through the East River by barge in 2009. Nowadays, the translocation of whole structures is mostly done for monuments, and buildings that have a historical value because this

Figure 7. Photography by Rob Bennett, transportation of the Nathaniel Lieb house onto a barge

kind of transfer involves a lot of work and it is often expensive. Initially it was mostly done as a way of keeping our heritage but nowadays it is also done for ecological reasons.

Otherwise, parts of a construction can be translocated, under the form of building components or materials that are not altered. Individual components can be extracted from one project and put into a another new building, somewhere else. This type of reuse can sometimes be called ‘component reuse’. This can be done for structural elements such as beams and columns but also for non-structural elements such as staircases, windows, doors or cladding panels. The reused element can have a very similar use to its first application. This is also known as ‘direct reuse’ meaning that « components are used as close as possible to their original state and for their original purpose, requiring almost no preparation »[1]. This way the elements conserve their form that was determined for a particular function. The reused elements can also get a new use or a new function for which it was not intended to be in its original conception, they are used differently than their first purpose. This is also known as ‘upcycling’. In this process, the form is conserved but the elements may be submitted to slight modifications, and depending on the element, they can be cleaned, repaired and refurbished. By doing this, two layers of information are passed onto the next generation, as civil engineer and architect Jean-Marc Huygen outlines: « the assembly of obsolete objects, with their forms

1 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p. 27

and their new use, appear like a new object but at a second level of reading, we recognise forms and information of the first objects »[2]. It also implies that new application fields can be developed for the recovered materials to imagine all the new feasible possibilities.

Furthermore, only the materiality of the building can be translocated. The construction is transformed and not recognizable anymore. The whole is crushed and the obtained material go back into the manufacturing process and this way new products can be made. This is also known as 'recycling'. It involves a deep transformation of the construction elements, as underlined in the book *Déconstruction et réemploi*, « recycling processes generally rely on grinding processes that brings the components back to the state of raw materials: solid wood is transformed into shavings, concrete into aggregates, plastics into granules, plasterboard into powder, glass into silica… These raw materials can then be used in the production of new elements »[3]. It is usual that the recycled materials are used to make products that are different from their initial use. For example, wood recovered from building demolition can be processed in order to make chipboards. Concrete aggregates can be reused into new concrete. With this approach, the form and information of components are destroyed. From the original building, the materiality is preserved and transferred.

Another possibility is to translocate the memory of a building, like a quote to remember what existed before. A way of doing so is by keeping the image of the building, and « the building can become a mysterious place of memories »[4]. This is done for example in the project of the German office Diener & Diener Architekten for the reconstruction of the east wing of the Museum of Natural History. The building set in Berlin was severely damaged by a bomb explosion during the Second World War and a part collapsed. The wing was rebuilt by molding the intact wing placed on the opposite side. This mold was then used to poor concrete and create a wall for the new façade. This approach allows to « present the façade with all its lost detailing (such as the window bars) and even the traces of wear and

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2 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.155, translation by Charlotte Astaes

3 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.8, translation by Charlotte Astaes

4 Muck Petzet and Florian Heilmeyer, *Reduce, Reuse, Recycle: architecture as resource*, Hatje Cantz Verlag, 2012 , p.189

Figure 8. Photography by Diener & Diener, façade
of the Museum of Natural History

tear accumulated over the years »[5]. All the marks that accumulated by the effect of time can be seen and they have given the building a singular identity. This allows to create a continuity between the original part of the building and the new part; it is hard to even distinguish what was existing and what is new. This approach allows to preserve an imprint of the building and in this project it was used on the same site but we can easily imagine that the mold created could also have been used somewhere else. So, in general, molds could be made from building façades in order to cast concrete on other sites. This way, the imprint and the image of the building are translocated, only an impression of what existed remains. In this approach, nothing physical is kept of the original project, only a stamp. The façade can tell two stories at the same time, from two different generations, one from the past with the traces and one from the present with the new materials used to make it. The memory implemented on the new building can become a way to share our common past. This last method does use a lot of materials and would probably not be the most sustainable solution but it still is an interesting approach to maintain and pass on the story and history of a building to the next generations.

5 *Ibidem,* p.193

DECONSTRUCTION

IN PRAISE OF A CAREFUL DISMANTLING

The city, seen as an urban mine, is a place with valuable items that have to be removed with great care, in such a way that they will preserve their form and value. In quarries, to do so, we would use the process of extraction. For cities, this action can be translated into the process of deconstruction where materials are physically and carefully removed to acquire these valuable resources. This permits to release the constituents that make up the whole. Deconstruction can be defined as « a process of selective disassembly of a building at the end of its life to recover materials and components or systems for potential reuse and recycling. It is an approach to building removal that can extract resources so they can be used for high value future uses »[1]. Deconstruction can be used to separate the elements very clearly and make sure that their translocation become possible. As much as possible could be recycled but if it done with great care, it will also enable the reuse of components.

In comparison to demolition, deconstruction is very different because of its « non destructive character allowing the recover intact materials »[2]. These will normally have no or minor damages. The extraction method needs a methodological approach and specific knowledge adapted for a careful removal. The elements are recovered by soft-strip by hand versus the demolition that is done by mechanical means. Deconstruction implies a necessary coordination between all actors. It is often labour intensive and it takes more time than classical demolition. It will probably also lead to additional costs. However, demolition only produces a pile of debris and deconstruction allows to create a stock of materials and

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1 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p. xiii

2 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.316, translation by Charlotte Astaes

Figure 9. Photography by Olivier Beart, careful dismantlementto recover the tiles

components that have a potential of being used for new constructions. To constitute this supply of materials, Julie Benoit and Grégoire Saurel from the association Bellastock write that: « deconstruction is a key step in terms of quality, quantity and diversity of collected materials »[3]. If not done properly, none of the recovered elements can have a further use. Other than the fact that the elements can be reused, deconstruction offers a couple of other advantages over conventional demolition. It allows to have less demolition waste into landfills and also it enables to preserve the embodied energy - « energy used in all the processes necessary to produce a material

3 *Ibidem*

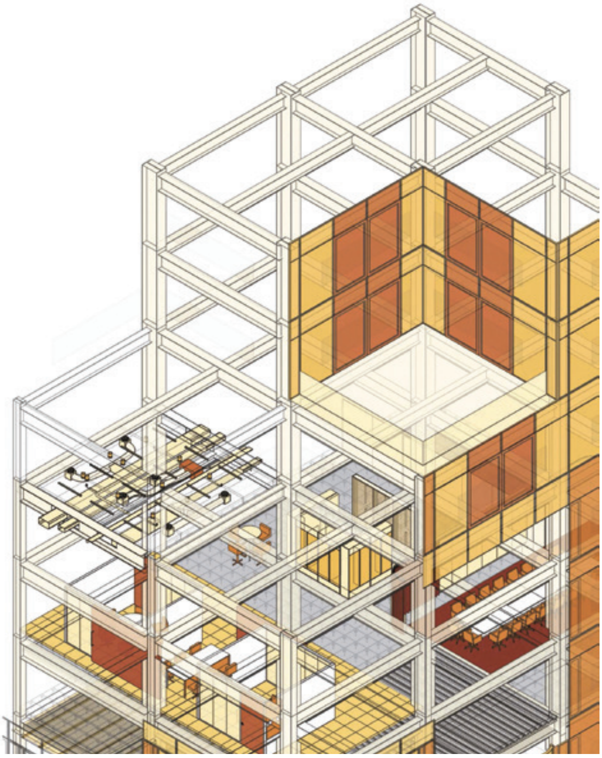

Figure 10. Illustration by Rotor, analysis of OMA's Timmerhuis, it allows to identify candidate elements to be reused

or component »[4] - of materials and thus reduces the input of new embodied energy in the manufacturing of new objects.

Deconstruction requires upstream and downstream work. Before starting anything, the construction and its assemblies have to be observed and comprehended. This initial visual understanding is very important to the smooth running of the deconstruction. The building has to be analysed to identify the present materials that can potentially be recovered. This analysis allows to measure if the components have any possibility to have a future use and it permits to organise the deconstruction by selecting the materials to keep as is and the ones that will have to be recycled. This analysis should also give specific data about the component such as technical characteristics, available amount and so on. This would help to make sure that the deconstruction is productive. During deconstruction, the steps roughly follow the reverse of the construction process. The

4 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p. xiii

materials that have been put on last, such as finishings and non-structural elements will probably come off first. This has to be done with proper tools and techniques. Downstream, after the extraction, deconstruction allows for the recovery of materials that then have to be sorted and stored. This step can facilitate the transportation to salvage yards and recycling centre. Some elements can then be transformed if needed. Once extracted, some salvaged elements will maybe need some repairs, rectification, or adaptation depending on its new use and what the future building needs.

The condition of many projects of reuse is a successful deconstruction, if the elements are not extracted correctly, the elements will not be used again and will finish into landfills. Deconstruction means the start of a new lifecycle for the materials and it represents « at the same time the end and the beginning of the construction »[5]. The application of deconstruction is not always as easy as we think and many elements cannot be reused because of different factors that will be addressed in the second chapter.

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5 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.310, translation by Charlotte Astaes

REUSE

THE GENERAL BENEFITS

Different aspects motivate people to reuse building elements. Indeed Reuse offers a few benefits. It has a positive impact on some ecological problems, it can offer job opportunities, pass on our patrimony to future generations and innovate the architectural profession. These benefits are the reasons why we are starting to find recovered elements in an increasing number of projects. They can help promote the general use of deconstruction and reuse.

First of all, the main reason for people to reuse is the environmental benefit of this approach. It is seen as a sustainable approach because it can help to reduce the impact of the building industry on the environment. On the one hand, less natural resources are extracted from the ground, putting less pressure on the landscape. Nowadays we live in a world of consumption where we buy, use and get rid of things very quickly, and our waste production only continues to increase. Such as the office Rotor underlines: « in a mass consumption system, the quantities of waste produced quickly cause accumulation problems »[1]. Reuse enables to lengthen the life cycle of materials by putting them longer into circulation before ending in the waste stream. This has as a consequence that the production and disposal of waste is reduced. Reuse can be seen as a prevention method, where elements are preserved a longer time and they are first seen as resources instead of being rapidly discarded. On the other hand, Reuse enables the reduction of energy consumption involved in the different activities surrounding this method. For the manufacturing of building components, energy is needed to extract, transport, produce and assemble, polluting as such the air by the release of gas emissions. If recovered materials are chosen instead of new materials, this can avoid the impacts

1 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.60, translation by Charlotte Astaes

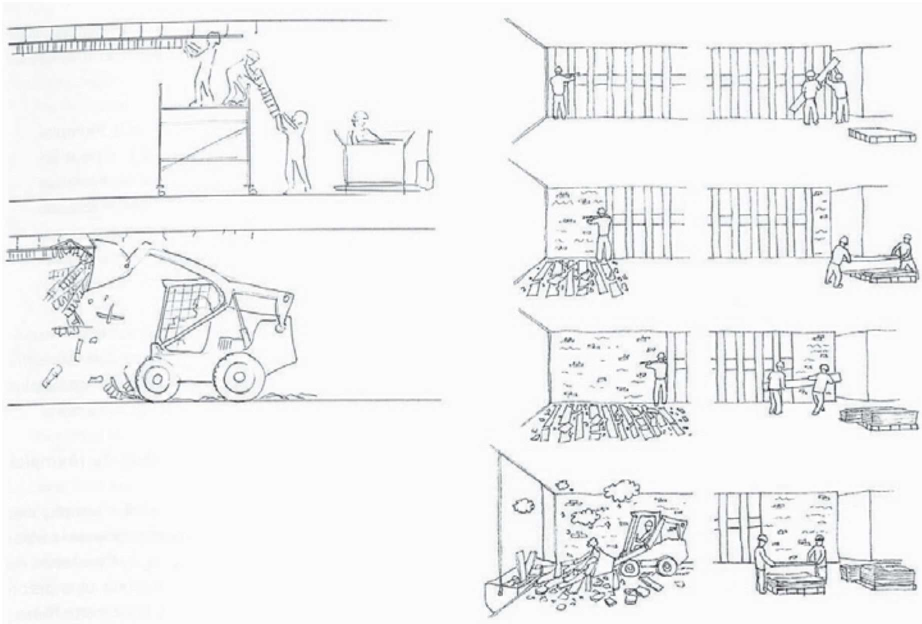

Figure 11. Illustration by Rotor, deconstruction requires more workers than demolition

of energy production and carbon emissions associated with the production of new elements.

Furthermore, deconstruction and reuse have an impact on the economy. Activities related to this approach are more labour intensive than recycling or traditional demolition and they need specific methods to be implemented. This can potentially create new job opportunities. The ratio 1:7 has been mentioned to point out that, for the same type of work, deconstruction involves about seven times more labour than classical demolition[2]. The use of machines in the non selective process of demolition involves lesser workers than the soft stripping process of deconstruction. This method is usually done by hand to make sure elements are not damaged. It requires finer work and hence is considered to be more labour intensive. However, the work of deconstruction can sometimes be repetitive and dangerous, and workers have to be sufficiently trained to manage the situations they are confronted to. Moreover, other types of jobs, relating to the process of deconstruction and

2 *Ibidem,* p.78

reuse, still have to be created because they do not exist today. In the document *objectif réemploi* [3], a series of suggestions can be found of new jobs that can be created or improved through the reuse of building components. Some example of professions they give are: the identification of the potentially reusable elements in buildings before demolition, extraction of the materials, cleaning and refurbishing, managing and transferring the materials, creating product documentation, handling and storing, and selling the items. Each type of work requires very specific skills. For now the labour force is pretty expensive in European countries. Besides, elements can still be shipped away in order to find cheaper workers before being shipped back to Europe and this can still be economically more interesting than hiring local labourers. But we can imagine that in a few years, costs related to transportation will increase and this will maybe help to implement more local jobs as reuse is directly related to the building's location, it can not be relocated.

In addition, reuse has a cultural and social impact. Building components and materials carry information with them and have different levels of reading. They refer to the origin by the materiality, the transformation process and know-how coming from workers or machines by the form and purpose they were given. The architect Jean-Marc Huygen underlines this idea by writing that « the reused object keeps its memory, the story it has lived, the love with which it was made or used, it is an inheritance »[4]. By reusing elements, all these layers of information are conserved and passed onto future generation.

Reuse also has an impact on the architectural profession. It pushes for creativity and innovations. To be able to use some elements again in a new situation, sometimes for a new purpose, original construction techniques, new types of assemblies and new types of shape my have to be imagined. Sometimes, custom-made parts have to be developed to enable the reuse of some components. For example, metallic structures are developed to assemble used windows for the building of the future seat of the European Council in Brussels. Other new types of construction

3 Michaël Ghyoot, *Objectif réemploi: pistes d'action pour développer le secteur du réemploi des éléments de construction en Région de Bruxelles-Capitale*, août 2017, p.23-27

4 Jean-Marc Huygen, *La poubelle et l'architecte: vers le réemploi des matériaux*, Actes Sud, 2008, p.12, translation by Charlotte Astaes

solutions will have to be developed by architects and engineers in the future. Original architectural forms, innovative projects and new types of implementation can hatch from this approach.

Reuse offers a interesting scope of different benefits. Because of this, it will probably continue to grow in the years to come. However, because of their recent application, deconstruction and reuse are confronted to a couple of challenges and limitations. These have an impact on the amount of materials that can be possibly removed from the building and then reused. The different criteria that come into consideration when it comes to the assessment of the building components and materials that can potentially be reused will be presented in the next chapter.

II

CRITERIA THAT INFLUENCE THE REUSABILITY OF MATERIALS

This chapter tries to understand the criteria that are used to assess which materials have the potential of being reused, and so, should be salvaged. They involve factors relating to construction techniques, contamination by hazardous materials, assembling techniques, the quality of the materials, strict building standards and regulations, concepts of beauty, and finally economics.

SITE ORGANISATION

THE STEPS NECESSARY FOR THE CAREFUL DECONSTRUCTION OF A SITE.

This chapter tries to underline all the steps necessary to the deconstruction of a site. Indeed, a deconstruction site needs a bit more organisation than a demolition site and this has an impact on the recovery of the various building components and materials composing a building. The management of the site includes different steps which need to be carefully coordinated: the time given to the deconstruction, the study of the diagnostic of the building and the preparation of the future operations, the handling of the items, the packaging, the transportation and finally the storage in the wait to find buyers willing to reuse these elements in a new project. All of these steps are essential to form a stock of valuable materials.

Figure 12. Photographies by Rotor, a few steps of a deconstruction process: dismantling, cleaning and sorting on pallets

The time given for the dismantling process

Today, we live in a world where everything has to go fast. We witnessed the acceleration of vehicles, of machines, and of information. We want instant results. Any time wasted is seen as a brake, a failure.

This same need for productivity has been observed in the construction industry where buildings have to be erected rapidly while previous sites still need to disappear. The time given to demolition today is limited and these time constraints do not allow for the careful dismantling process of reusable elements as this action requires significantly more time than classical demolition. It is said that the « time required for disassembly may vary between three to eight times that of mechanical demolition »[1]. The time given for the dismantling process in the construction planning is a crucial factor when considering what can actually be dismantled and recovered but « often by the time the demolition contractor is contacted, the project owner is under a time constraint requiring construction to begin in a matter of days »[2]. If nothing changes and the same time ratios are kept, the recovery of as many elements as possible from the site will not be feasible, and as such deconstruction may not be a viable alternative to demolition.

A solution to this problem is to start the assessment of the elements as soon as possible. The period preceding a demolition or transformation despite being tighter and tighter is still relatively long. It is not uncommon that many months goes by, if not years, between the moment the decision to demolish is taken and the moment the work actually begins. Advantage can be taken of this period to organize the disassembly of the possible reusable materials: identify them and plan the disassembly to actually try to be more prepared and this could help to acquire more materials.

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1 Fernanda Cruz Rios, Wai K. Chong and David Grau, *Design for Disassembly and Deconstruction - Challenges and Opportunities*, International Conference on sustainable design, engineering and construction, p.1301

2 Charles J. Kibert, Abdol R. Chini and Jennifer Languell, *Deconstruction as an essential component of sustainable construction,* CIB World Building Congress, April 2001, p.4

A diagnostic to identify the materials that can be reused

Establishing a diagnostic before deconstruction is the key step in assessing the quality, quantity and diversity of materials collected. The preparation must be carefully studied and planned, in consultation with all the stakeholders, to optimize time, manpower and material flows. A diagnostic has to be done on the building to assess what is salvageable. It implies a study of the whole building to identify all the materials and building components that can be recycled, the ones that are suitable for reuse and the ones which are considered to be waste and need to be disposed of (asbestos, lead and other hazardous substances). Moreover, the diagnostic identifies all the elements present on the site such as access roads for the machines or existing networks and it also defines the machineries that should be brought to the deconstruction site as well as the removal techniques that will be needed.

The site will then be prepared with the necessary installation to help with the process of dismantling. Stairs, scaffolding and elevators can be brought to help with both the moving of the elements and the workers around the site.

In this step, people who might be interested in buying the elements should be contacted and given explanations as to where they can find these elements once they have been recovered. The elements can be reused on site but they can also go to salvage yards or they can be directly bought by firms or individuals who will take care of the storage themselves.

The handling and removal of materials

The process of deconstruction itself can be separated into several distinct actions. Firstly, all the waste existing on the site coming from prior occupation or from the abandonment of the building (e.g. squat waste) is collected and eliminated. Subsequently, all hazardous waste that threatens the safety of the workers (e.g. asbestos) when deconstructing is disposed of. Moreover, all the non structural elements (e.g. finishing products, windows, insulation, etc.) are removed. Removal is carried out manually or by light mechanical means. Generally speaking, the structural elements are

Figure 13. Photography by Stephan Kampelmann, disassembly and preparation of window frame on pallets, 2017

– if possible – dismantled with the appropriate tools and – when it is not possible – they are demolished. There are different ways to demolish a building depending on its environment, height and so on. The easiness of the items to be handled with will have an influence on the possibility of reusing them. For example, a heavy object will ask for more specific machines which cannot always be brought to the site. If the means are not at our disposal, reuse will not be possible. Finally, once the elements have been dismantled and collected, they should be sorted between what goes to recycling facilities, landfills or salvage yards.

In an *in situ* deconstruction site, meaning that the elements do not leave the site, they must be supported by the project's stakeholder – the architect, contractor or owner – and this person must assume the logistic supervision, the possible treatment of the elements and also the storage. The person also has to verify that these elements respond well to the performance requirements of the new project. For a deconstruction site where the reuse will be *ex situ*, it is possible to use the services of professional operators. This would ensure an efficient and professional handling of materials and packaging.

The packaging and transportation of salvaged materials

Once the elements have been sorted, they should be packed in order to be transported to a specific secondary location. The packaging process is important to make sure that everything is well protected before being transported. There are different types of packaging, depending on what kind of elements are being handled: plastic wrapping, plastic crate, carton box, pallet, wood crate, container and others. Once properly packed, the elements are usually transported from one place to the other by truck.

In the case of a deconstruction *in situ*, meaning that the dismantled elements will actually be used for a construction on the same site. The act of packaging, transportation and storage does not exist. The elements that would have been hard to transport by trucks because of their weight or size can more easily be reused as they do not need to be moved. Hence more elements can be reused.

The storage of recovered materials

The recovered materials and building components require to be stored. So far, salvaged elements can be stored in different ways: while some of them can either be returned to specialist firms or to the original manufacturers for reconditioning, most of them will go to salvage yard – a place where the elements are stored and sometimes refurbished before they find a buyer who wants to use them. However « currently in most developed countries there is a lack of a supply chain for reclaimed materials and components, particularly for acquiring a uniform supply in large quantities suitable for larger projects »[3]. The problem is that often these salvage yards are not very big and it can be difficult for the architect to find enough materials for his project.

The condition in which the elements are stored is also important and they have to be appropriate for the different types of elements. For example: « inert elements can be stored outdoors without fear of the weather. Other materials require more adapted

3 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p. 44

storage conditions. This technical question joins here economic considerations that refer to the question of the price and availability of storage space »[4].

It is essential that salvage yards expand in the future or that other types of storage spaces are developed because this would allow for extra space to store all the elements. That is why some architects have put into place some platforms that inventory retrieved materials. Through a better communication, the supply and the demand of these kind of elements could increase. Some examples of such places are the site Opalis.be from Rotor architects or Oogstkaart.nl of the group SuperUse.

4 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.99, translation by Charlotte Astaes

LE GRAND DETOURNEMENT

Bellastock

2012

Urban furniture

Saint-Denis / France

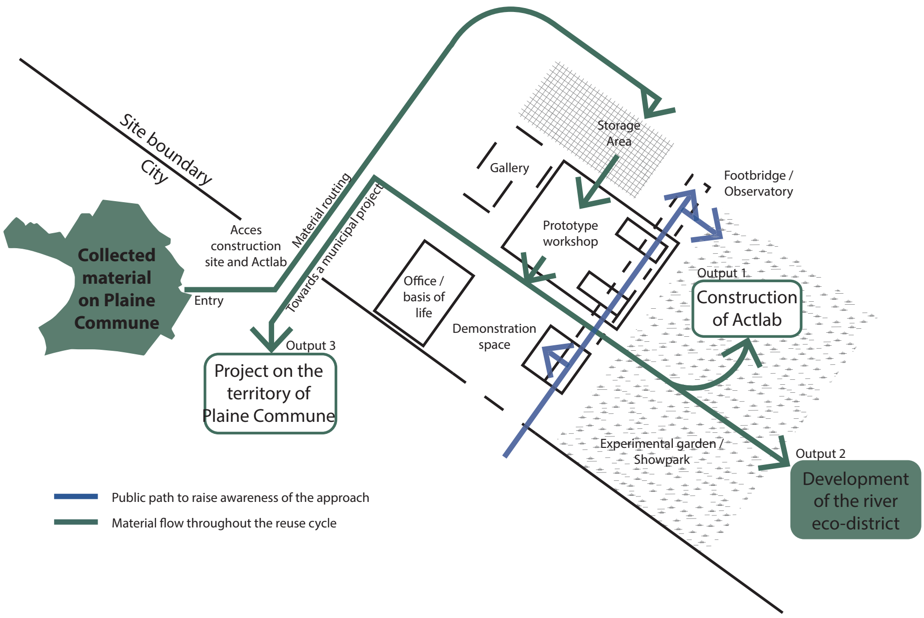

Figure 14. Illustration by Bellastock, organisation of the site on the Île-Saint-Denis eco-neighbourhood

Opposite page

Figure 15. Photography by Alexis Leclercq, volunteers working on the site

LE GRAND DETOURNEMENT

Bellastock

Presentation of Bellastock and the project

Bellastock is an association of architecture that works on the cycle of materials. Every year, with 1000 participants, they create an ephemeral city. The 2012 edition of this festival was called “Le Grand Détournement” and the topic of this festival was the reuse of materials. The action took place where the new eco-district of île-Saint-Denis is going to be erected. The actions of Bellastock was to use the industrial wasteland existing there, more specifically the abandoned *Printemps* warehouses, a giant of concrete fallen into disuse after 30 years of exploitation. This festival was used to introduce two different projects of Bellastock Actlab, platform to test reuse and Repar, the research and expertise program on reuse.

Figure 16. Photography by Thomas Béhuret, “93450 Mutations”, the Printemps warehouse before demolition

In 2012, the abandoned warehouses were discovered. They had been standing since 1950 and were abandoned around 1990. The buildings were colossal, covered with graffitis and all the copper had been stolen. However the structures were still intact. These were going to be demolished in February 2013 but Bellastock saw them as a deposit of materials for construction that could be used to built furniture and small scale projects for the public spaces of the future eco-neighbourhood of Île-Saint-Denis. The materials gained value as they could be used to develop new activities on the site. ADEME (Agence de l'environnement et de la maîtrise de l'énergie) gave them the assignment to experiment with an *in situ* reuse sector. This means that Bellastock ensured that all the materials that could potentially be reused would not leave the deconstruction site. For this they wanted to be present on the site and they did so by constructing the Actlab laboratory in the middle, to be able to work with the collected materials directly and follow the deconstruction of these warehouses during a period of two years. This permitted an economy in transportation and in storage. Furthermore, the materials on the site were seen as a resource and not as waste. Actlab has been constructed and adapted through time depending on the arrival of materials to be reused. In addition, they sorted and tested the materials themselves, prepared them for reuse by restoring them when needed and implemented them into new projects. All of this asked for a precise organisation of the site.

The building diagnostic and site organisation

Repar first studied the demolition of the Printemps warehouses. The archives of the city were studied to find information about the building and the materials used during construction. Further, a waste diagnosis had to be done on the building to find hazardous materials such as lead and asbestos making reuse impossible. They also conducted some interviews with insurers and developers to get a guarantee for the reuse of the elements.

To organise the deconstruction site, before starting the dismantling of anything, a time planning was implemented and also the areas where the collection of the materials would happen was planned. All the actors involved in the demolition and the project were mobilized to explain the steps and become more sensitive about all of it.

They produced a document to list all the elements qualified to be deconstructed and then reused for the demolition workers. This inventory described all the recoverable materials: the quantity, the collection procedures and the visual quality controls that had to be performed during the operations. On the same day, the proposition of principles on how these listed materials could be reused in further construction for the public spaces were shown to the urbanists. From this, six urban furniture and constructive systems were decided on, mainly from concrete (beams), metal (plumbing tubes, rails) and other elements.

Experiments to find the most adequate removal technique

After the time of the diagnoses came the time of collection. With the help of Doyère, a demolition company, they progressed on the question of how to properly remove elements without altering them. For this, they used removal tools that do not alter the mechanical properties of the materials such as light mechanical means for the metallic elements and they grinded the concrete with the help of a demolition grapple.

Some different techniques had to be tested with the existing tools to find the most appropriate one. For example, the most removed elements in concrete were beams or grinded pieces of concrete. The concrete had to be identified first to choose the most adequate pieces, that looked to be in better quality. Three methods were then tested to crumble the material: a demolition grapple, a felling head and a grinding machine. Finally the first method was chosen as less material was lost. Because suitable tools do not always exist, experimentation with different existing devices helped to make sure the best technique was used.

The preparation and repair of recovered materials

Once collected, the materials were delivered in the buffer space situated in front of Actlab to start all the steps of preparation for reuse. In this intermediary space, they were laid loose, roughly arranged and sorted. Basic controls were then made on the materials by visual observation and simple gestures, only to keep the elements whose mechanical properties had not been altered beyond a given level of requirement through the way they were dismantled. For example, concrete columns should not be fragmented, and bricks should not sound hollow or have cracks. After that, the received materials entered the workshop space to be standardized and restored, by hand when possible.

Various implementations for the salvaged materials

Finally, prototypes were made from the recovered materials. For example, a path was designed and built with fragments of concrete coming from beams of the primary structure of the warehouse, volcanic rock sand from the insulation used in the roof and sand from the soil of the demolition site. Also, a footbridge was built to provide a place of observation. It was made from IPN beams from the rails used to transport goods in the warehouse and also metal tubes that were recovered from the fire network of the building and used for the railings and for the lamps.

Figure 17. Photography by Bellastock, footbridge built during the festival Le Grand Détournement

CONTAMINATED MATERIALS

THE STEPS FROM THE IDENTIFICATION TO THE DISPOSAL OF HAZARDOUS ELEMENTS.

The contamination of an element means that it has been « made impure by polluting or poisoning »[1], in other words the contaminated element is corrupted. These elements become undesirable and mostly known as hazardous materials in the construction industry, meaning that they are dangerous and they involve a risk, especially to someone's health.

In the building industry, the most known hazardous materials are 'asbestos' and 'lead-based paint elements'. They cause a contamination of the surrounding area in which they are. The use of asbestos is very diversified and it can be found in walls, insulation and floors. Lead-based paint is commonly found on window frames and on surfaces. They present risks to people living in the building but also to the workers if not handled properly.

Other elements that also carry risks are 'coal tar', 'creosote' and 'mercury'. Coal tar is present in some products such as glue for wood flooring, mainly used around the 60s. Creosote is a substance that can contain coal tar and is frequently used as a pesticide to protect wood standing outside. Mercury is particularly present in measuring instruments or radioactive products which can be found in some instruments and in security lighting fixtures. It is written in the book *Déconstruction et réemploi* that « All these products are banished on contemporary sites but we find them frequently in buildings built before the entry into force of regulations »[2]. For example Asbestos was banished from most constructions after the eighties.

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1 Oxford University Press, Definition of contamination in *Oxford Dictionaries*, (s.d.), retrieved november 25, 2018 from https://en.oxforddictionaries.com/definition/contamination

2 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.161, translation by Charlotte Astaes

Figure 18. Photography of a surface contaminated by lead paint.

Figure 19. Photography of a lead paint testing kit

Identification of hazardous materials and testing

Before deconstruction or demolition, the elements that present a risk of contamination have to be identified and tested. This will first be done by a visual scanning of the building and then further tests are done in laboratories. Some tests can be done directly in the building to give a first assessment. On site, for example, this can be done in the case of lead-paint, through the use of portable kits that exist today on the market. These give an immediate result, an example of this kind of kit is the 'Lead Check' of the 3M organisation[3]. Sometimes, if a doubt exists about the presence of hazardous materials in the building, samples of elements have to be taken on risky sites and brought to laboratories to be tested before actually removing anything. These tests are done for asbestos, coal tar or if a further diagnosis for lead paint is needed. This helps to assess the risks associated with each materials and determine if their reuse is desirable.

3 *Ibidem*

Removal of hazardous materials

If elements that present a risk of contamination have been identified in the building, these have to be carefully handled and this will have an impact on the progress and organisation of the deconstruction or demolition site in such a way that it does not contaminate other parts of the building making them also unfit for reuse. This was the case in 2016 when « during an operation of decontamination carried out in former barracks intended to be converted into housing, in Reuilly, in the Paris region, the treatment of lead paint led to the disqualification of wooden elements that were nevertheless reusable. Insufficiently protected during the operations, they absorbed lead dust, which definitively compromised their reuse »[4]. Also workers working on the removal of hazardous materials should have the proper information and expertise to work on it. They should also have protective gears if needed and safety measures have to be taken on the building in order to make sure that the workers are in no danger of exposure.

Disposal of hazardous materials

The elements, once they are removed need to be packaged properly and disposed off. They can not just go anywhere and « hazardous materials are required to be disposed of in a lined landfill or other disposal facility that is permitted for those materials »[5].

Some hazardous elements can be intended to be reused if they have been treated. For instance elements containing lead-based paint traces or materials that have been repainted to encapsulate the lead paint. If this is the case, there should be a notification on the element to inform people who are handling or storing the materials. These kind of elements are not allowed to sit exposed on the ground where there is a potential for the lead paint to leach into the soil. They should be stored on « 6 mil polyethylene sheeting and a waterproof

4 *Ibidem*, p.99

5 Bradley Guy and Sean McLendon, *Building deconstruction: reuse and recycling of building materials*, Center for construction and environment, p.6

covering »[6] or they should be brought to suitable storage facilities. The use of some hazardous materials, is forbidden by law and they cannot be reused. Yet some can be recycled, this is the case for some examples of asbestos.

6 *Ibidem*, p.8

THE CASE OF ASBESTOS

A well known hazardous material

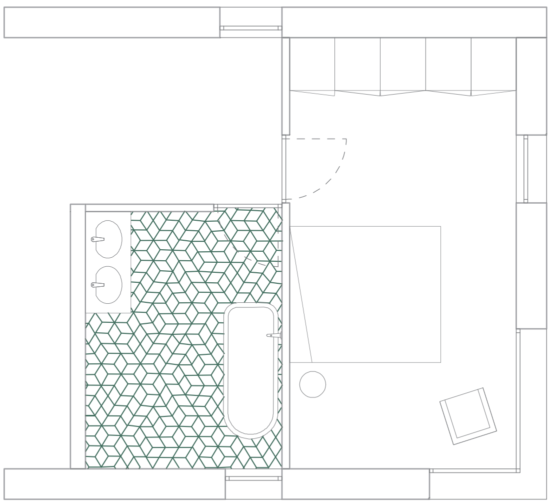

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Figure 20. Plan drawing of floor tiles made from recycled asbestos

Opposite page
Figure 21. Photography by Simon Thiebault, the laying of Cofalit floor tiles

THE CASE OF ASBESTOS

A well known hazardous material

Asbestos is a naturally occurring material that is made from long thin fibres. It was commonly used in building materials before the 1970s, and its use is very diversified. It can be found in walls, insulation and floors because of its valuable properties of resisting to fire, not reacting with chemicals and is also a quite strong material that is rather durable. It can be assumed that almost all buildings constructed before the eighties contain asbestos.

Figure 22. Photography of workers removing components contaminated by asbestos

Risks involved when exposed to asbestos

After asbestos had been used for some years, it has been discovered that actually asbestos is really dangerous when inhaled as dust, it is a carcinogen and it can cause serious illnesses if not handled properly. Asbestos is made of microscopic fibres that are easily inhaled and can get lodged in the respiratory system. If inhalation happens, there is an increased risk of having lung cancer, asbestosis that is a chronic lung condition where the lung tissue is scarred and mesothelioma that is a rare type of cancer of the lining of the chest and the lining of the abdominal cavity.

Old buildings are bound to have asbestos somewhere because it was used so widely before, so there is still plenty of materials containing asbestos out there that have to be dealt with very carefully.

Tests to identify the presence of asbestos

An expert of an asbestos surveying company will be contacted to identify whether asbestos is present on site and he will « assess the potential risk for fibres to be released and become airborne »[7]. Samples of areas at risk will be taken and tested in laboratories. If any part of the building has been tested positively to asbestos contamination, the location has to be clearly marked.

In the book *Déconstruction et réemploi* by Rotor, they explain that « in the area of asbestos detection, a new product is currently under development. It uses laser technology and the paramagnetic properties of asbestos fibers. It can detect abnormally high densities of asbestos fibers in the air. This technology is based on the analysis of the movement of fibers in the air. It therefore does not detect the presence of asbestos in a building element. They play the role of the canary in the coal mines, whose sudden death indicated a dangerous concentration of explosive gas in the galleries. This device could be used to quickly alert workers if a dangerous change in ambient air quality occurs. One can reasonably imagine technological breakthroughs allowing the appearance of point-and-shoot devices that could identify materials containing asbestos fibres »[8]. Development and research make it possible to invent better tools to identify hazardous elements making it less dangerous to work in these environments and possibly the recognition could be done faster in the future.

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7 Citizens Information, *Dealing with Asbestos*, page edited 27 January 2015, retrieved december 22, 2018, from http://www.citizensinformation.ie/en/environment/ environmental_protection/ asbestos_regulations.html

8 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.164-165, translation by Charlotte Astaes

Removal of asbestos-containing materials

Removing asbestos-containing material is a complex procedure and must only be done by specialists. Asbestos waste is dangerous and improper removal increases the risk of fibre inhalation. There are detailed rules about how the waste should be wrapped, labelled and disposed of and « A series of regulations have been made to ensure that workers are protected from risks related to exposure to asbestos at work. They apply to all places of work and all sectors of work where asbestos-containing materials may be present »[9]. Asbestos should be removed by hand and should not be crushed, cut or grinded making it possible to release some dangerous dust in the air. The removal of asbestos should be done before any demolition or deconstruction actions are taken otherwise the entire demolition waste is required to be disposed off in an asbestos certified landfill because all the debris could be contaminated with asbestos.

Asbestos removal companies will completely enclose any areas with asbestos and the work has to be planned in such a way that the contaminated elements are disturbed as little as possible and everything possible should be done to keep the amount of asbestos in the air to a minimum. Workers have information provided, instruction and training to know what risks are involved and what precautions have to be taken. They have to put on respirators and protective gear depending on the level of asbestos in the air before they remove the affected pieces.

Disposal of contaminated materials

Properly disposal of any waste that contains asbestos is important. There are detailed rules about how the waste should be wrapped. In Europa, UN-approved red bags have been implemented that have an asbestos warning label on them that then have to be sealed with duct tape in which all asbestos waste, debris and

9 Citizens Information, *Dealing with Asbestos*, page edited 27 January 2015, retrieved december 22, 2018, from http://www.citizensinformation.ie/en/environment/ environmental_protection/asbestos_regulations.html

contaminated materials have to go in. If something can not fit in the bag, at least two layers of polythene have to be wrapped around it and the red asbestos bag or a printed label should be attached to it to show that it is asbestos waste. Asbestos waste should then be transported and be disposed of in a landfill that has a specific permit authorisation for this kind of waste or it should be brought in an appropriate recycling facility.

The possible recycling of asbestos

A material or an element contaminated by asbestos should be considered as unfit to be reused. The placement of asbestos or asbestos-containing products on the market is today illegal, under the European Communities (Dangerous Substances and Preparations) (Marketing and Use) Regulations of 2003[10] . So today, it is not possible to reuse building components that are made with asbestos because of the law.

Reusing asbestos is today not possible but it can actually be recycled. When heated to very high temperature, more than 4000 degrees, the asbestos is vitrified and turns into silicate glass and it becomes completely inert. In this form, it is inoffensive and do not present any danger to the health. Afterwards, this silicate glass can be used to create ceramic products. For example, the designers Gaëlle Gabillet and Stéphane Villard use this technique to make floor tiles and refractory bricks that can resist high temperatures and diffuse heat. Used like this, the material becomes completely safe, this is made possible through technological advancements and research.

10 *Ibidem*

ASSEMBLING METHODS

THE DECONSTRUCTIBILITY OF A MATERIAL DEPENDS ON THE TYPE OF ASSEMBLAGE.

The technique of assembly and the nature of junctions is an important factor in defining if a material or building component can be reused. Some of these techniques are simple to reverse making it easier to recover the elements without damaging them or at least not too much. They can easily be refurbished and restored into a sufficient condition for reuse. Also the accessibility to the connections and jointing methods in the building itself become important. If there is not enough space or if the jointing method is not easily accessible, it will not be difficult to recover the element in a good state.

Traditional techniques of assembly

Different techniques of assembly exist and Jean-Marc Huygen, in his book *La poubelle et l'architecte*[1], outlines that people usually differentiate two types of assemblies: the 'dry' and 'wet' assembly techniques. The wet construction implies the use of a fluid, in most cases water and it will need a drying time to set. This should happen in particular conditions and temperature. The dry construction, on the contrary, does not need any water but needs a particular action or an intermediate item to fasten the elements together. This assemblage can be prepared in a workshop or in an industry and brought afterwards on the construction site. At the end of a building's life, the dry assembled structure can probably be dismantled with minimum damage making this type of assembly more convenient for reuse while the wet assembled structure will have to be broken into rubble and in best cases these rubble will be recycled.

1 Jean-Marc Huygen, *La poubelle et l'architecte: vers le réemploi des matériaux*, Edition Actes Sud, 2008, p.120-123

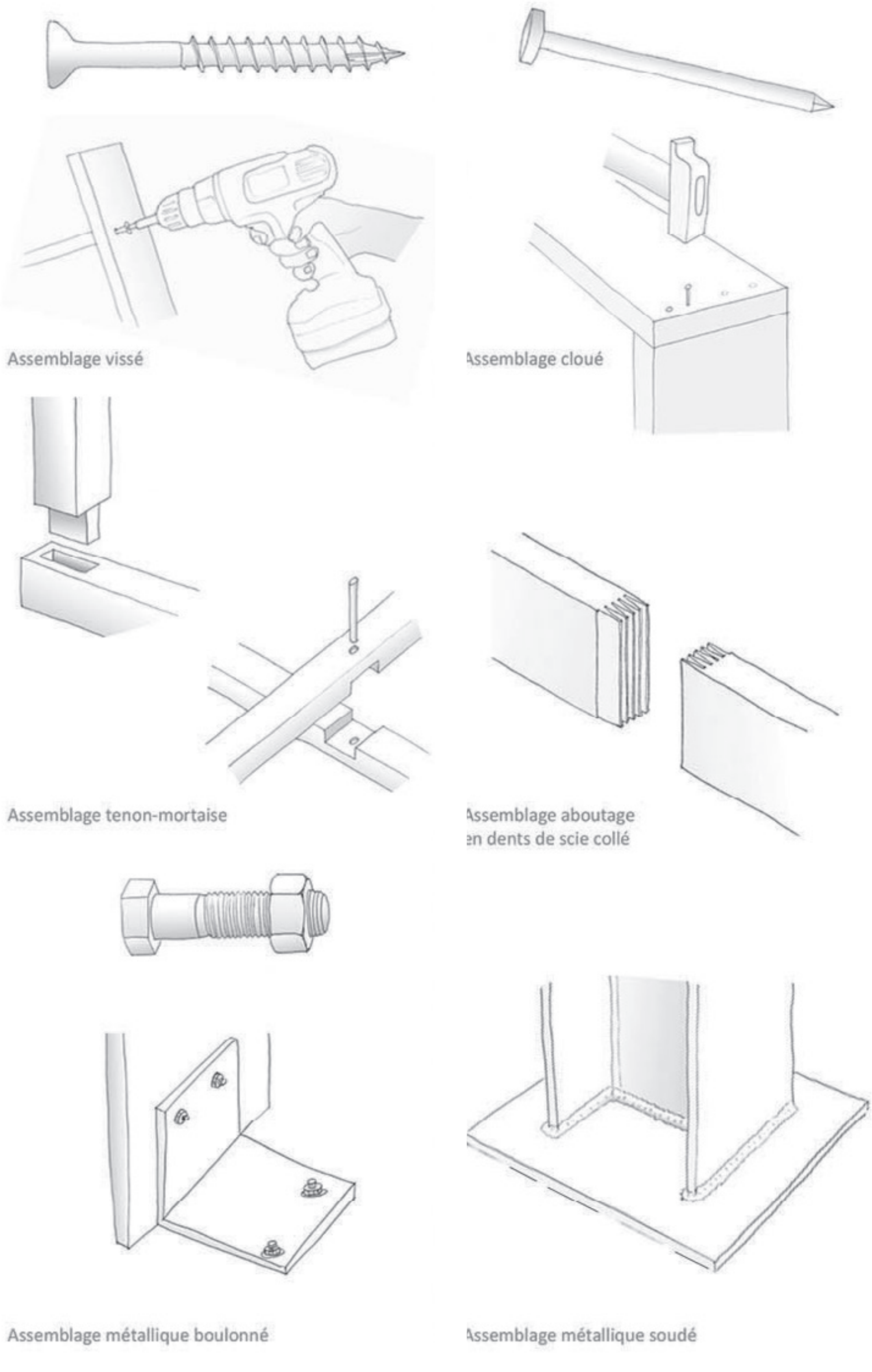

Figure 23. Illustrations by Ingrid Bertin, somes types of assemblies and their reversible equivalent for different materials.

Some examples of dry assemblage are weaving, the interlocking of elements, screwing, nailing, bolting and many more. Most of these techniques are easily inverted and the element easily reused but it is not the case for all of them. For example, chemical and welding connections are not reversible and components are more easily damaged in comparison to using bolted, screwed or nailed connections.

Different examples of wet assemblage are concrete, mortar, paint, adhesives like glue and so on. This type of assembly can be used to bond elements, such is the case of mortar connecting bricks but it can also become the material itself, like concrete.

Challenges linked with 'modern' techniques of assembly

With technical evolutions, some assemblies and materials became more complex. As underlined in the book *Déconstruction et réemploi* [2], the list of materials used for construction has not changed over nearly eight centuries. These materials, by their composition and their method of implementation, were suited for reuse and recycling. However, since the industrialisation, machines have been replacing human hands. With the idea of efficiency of production becoming more important in the building industry, new types of assemblies were created to construct faster. The connections became more and more complex and also less reversible.

Furthermore, there is a lack of appropriate tools for this kind of dismantling. Devices for deconstructing actual buildings often do not exist and these have to be invented to help recover more elements. Existing tools could also be slightly adjusted to make them more appropriate for dismantling building components without damaging them.

Additionally, the access to the attachments is essential. For a safe and complete removal of components, the connections have to be physically accessible and there should also be enough space to handle the appropriate tools around the jointing without damaging anything when trying to manoeuvre the tools around.

2 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.106

Solutions for future designs

For future buildings, architects should think about which structural assemblies they use in their buildings and what will happen if one day the building is going to be dismantled. Some solutions already exist and they privilege mechanical assembly techniques such as underlined in the book *Resource salvation*: the architecture of reuse: « flexible and reversible connections are seen as a prerequisite for dismantling. This mechanical fastenings are preferable to chemical bonding. Connections can be exposed, which makes dismantling easier and can be directly linked to tectonics and expression of joints - weaving, stacking, patterns and so on »[3]. A focus should be given on using dry-jointing techniques and new ones should be developed to replace the wet assembly ones which should be forgotten. New techniques would avoid interpenetration between the connectors and the components. These last ones should stay independent and exchangeable. Also, taking a closer look at ancestral methods, neglected through time because of technological advancements could be interesting and these could be modernised to avoid irreversible jointing. Interlocking joineries already exist for wood where no glue is used to connect them. Maybe it would be possible, with research to find similar solutions for other types of materials. For example, the company Daas Baksteen in the Netherlands has developed a product called 'clickbrick' where bricks could be attached mechanically to allow the dismantling. The bricks are assembled with a stainless steel clip instead of mortar[4].

Furthermore, by merging knowledge and technologies, new tools could be invented and developed to make sure more appropriate tools exist on the market. For example, a non-profit organization called The ReUse People specialized in building deconstruction try to use tools that damage the elements as little as possible. One of these tools, presented in the book *Behind the Green door* is the 'Reconnx Nail Kicker'[5] that is a pneumatic nail remover, used to de-nail timber and flooring without damaging them. Even

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3 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p.54

4 Rotor, *Behind the green door: a critical look at sustainable architecture through 600 objects*, Oslo Architecture Triennale, April 2014, p.132

5 *Ibidem*, p.131

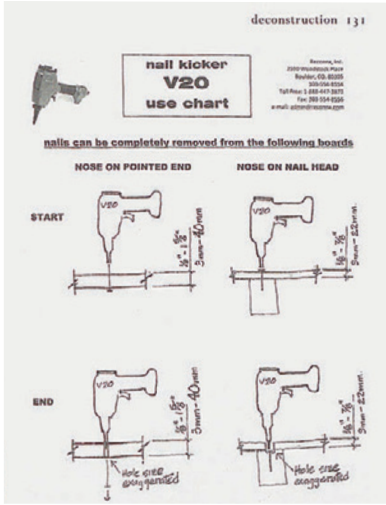

Figure 24. Photography and illustration by the ReUse People, Reconnx Nail Kicker pneumatic nail remover and instructions

if it said that the use of screws is better because there are easier to spot on the wood and it is easy to unscrew them, nails actually only slightly modify the material once pushed in it. Also if the screw head is to damaged or deteriorated, it becomes almost impossible to remove. So, the development of specific tools such as the 'Nail Kicker' can help with some types of assemblies and not deteriorate the materials and make it more easy to reuse the elements. Some markets dealing with devices like this one can still be developed in the future. Probably, also existing tools could be slightly modified or used in another way as it was intended to can help with the removal of elements.

These ideas can be found in the concept of design for disassembly, an approach that « aims at the design of transformable building structures made of components assembled in a systematic order suitable for maintenance and reconfiguration of their variable parts »[6]. The end of life of the building is already anticipated when designed where assemblies are thought of permitting an easy separation of components.

6 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p.50, Definition given by Elma Dumisevic and Ken Yeang

RESSOURCE ROWS

Lendager Group

2015-2019

9148 m²

Ørestad / Denmark

Residential complex

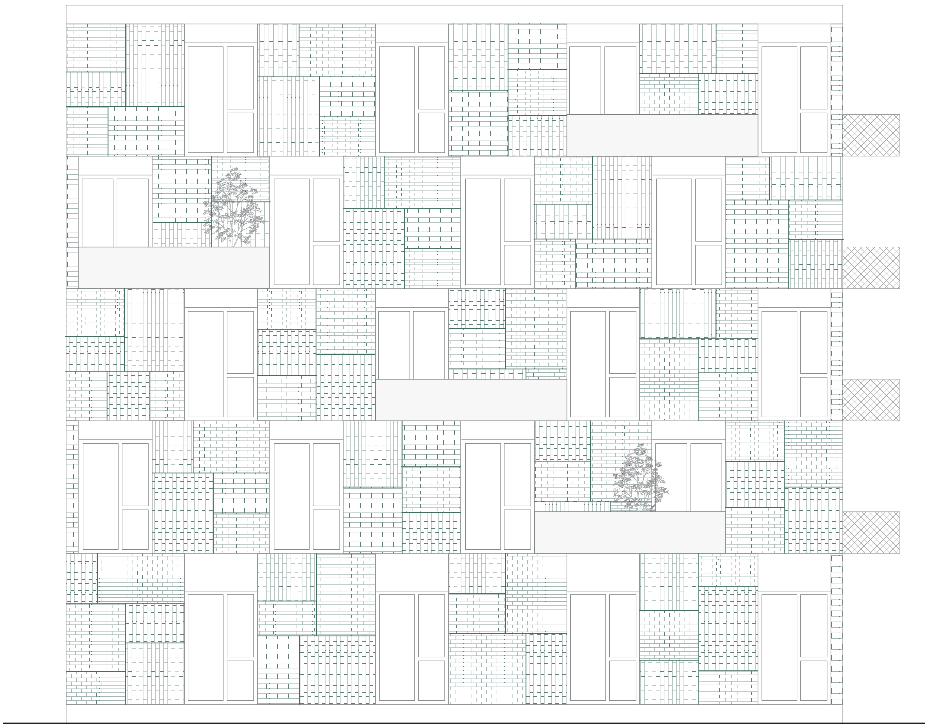

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Figure 26. Photography by Seier+ Seier, construction site of the project Resource Rows

Figure 25. Elevation drawing of the project Resource Rows

RESSOURCE ROWS

Lendager Group

Nowadays, many buildings are made using the wet assembly technique and lots of them will probably be demolished in the next few years. Solutions on how to reuse the building components when they will be demolished should be thought of . A case study is herein presented to see how to get around the problem: Resource rows of Lendager Group in Copenhagen

Presentation of Lendager group and the project

Lendager group is a sustainable architecture office based in Denmark specialized in the promotion of circular economy within future cities and wants to offer concrete solutions through their projects. The projects they work on always try to balance social, economic and environmental aspects in order to be sustainable by for example using upcycled materials that they develop and produce themselves locally. By using this approach they want to give a new value to the waste resource that lost their potential and create aesthetic products giving an answer to our environmental worries.

The project called resource rows is a new residential building that will be built in Ørestad Syd, a new development area in Copenhagen. It consist of 29 row houses and 63 apartments made of upcycled building materials. Collecting rainwater for toilet flushing and irrigation, living in a community that shares resources and integrating nature on the roof and in the courtyard become important aspects of this project. The most crucial attitude in this building is the use of materials that come from abandoned buildings from around Denmark and from Copenhagen. Numerous people seem to be trading rural areas for cities, leaving their houses empty and Lendager Group wants to make the best use of all available resources. They have « identified that Denmark has about 60 000 abandoned rural houses »[7]. So the main concept is to reuse the brick façades from abandoned homes directly in the new building by cutting the façades of the abandoned homes.

The evolution of mortar makes disassembly more difficult

These abandoned houses are mostly made from brick façades with cement mortar and not from lime mortar anymore. This makes it difficult to recover the bricks.

Mortar is used in construction and most commonly for the assembly of bricks. It is a mixture of sand, water and a binding agent, for example cement. Additives can also be added in order to adjust the mortar to its use. Lime mortar is one of the most commonly used binder in older buildings and is still used on some cases. It is said that this type of mortar allows the wall to breathe better and that it has water repellent properties. The drying time of lime mortar is longer, this can be seen as a problem when the idea is to built fast but it allows an easier application because of its longer drying time. This mortar is also more complex to dose than cement and is not as strong. That is why a new type of mortar has been developed: the cement mortar. It is the most basic product available today and is most often used to bind stones or bricks together. It is a mixture of cement, sand and water. The advantages of cement is that is has excellent compressive strength and it dries faster than most other solutions. In some mortars, both lime and cement can be mixed, making the mixture more flexible and easier to apply than cement mortar.

This evolution in the process of making mortar happened in the 1960s and has made it more complicated after this period to reuse individual bricks. With the cement, the mortar has become stronger than the actual brick having as consequence that the brick breaks when tried to be disassembled separately.

7 Mark Gorgolewski, *Resource salvation: the architecture of reuse,* John Wiley & Sons Ltd., 2018, p.235

Figure 27. Photographies by Lendager Group,
worker cutting up brick modules and modules ready
to be transported

Modules made from abandoned brick buildings

In their project resource rows, Lendager group experiment a possible solution where bricks would not be disassembled separately but where they are cut into small modules and then assembled in bigger modules that then are stacked to create new exterior walls for the building. This comes from the fact that the very strong mortar holding the bricks together. They have been developing this module themselves with some collaborators and some prototypes were tested before the construction started.

To make this building possible, Lendager has worked in collaboration with the development company Carlsberg Byen to cut out brick modules from Carlsbergs historical breweries in Copenhagen. Otherwise, the bricks of the brewery would have been used as crushed road fill. The rest of the bricks come from various old schools and industrial buildings around Denmark.

The façades are cut into pieces with appropriate tools. It is not sure if the tools which were used already existed or if they had to invent new ones. The most probable idea is that they used an existing machine in a way for which it was not designed for. The elements are then packed and protected with the use of pallets and

Figure 28. Photography by Lendager Group,
production of the brick module

a wooden structure to subsequently be transported to the place where the modules are made. Once arrived, they are carefully installed in a steel frame next to each other. A thin metallic element is added between the different modules to help holding them together. It seems that concrete is then poured to bond all the small modules together into one bigger module which can then be installed as a facade element on the new building. Each module consist of between six to nine modules. The result is a patchwork with different colours and slight changes in depth because the brick modules are not all the same size.

THE QUALITY OF MATERIALS

THE CONDITION OF A MATERIAL HAS AN IMPACT ON ITS REUSABILITY.

When a building is going to be deconstructed, the elements have already been used for some years and they might be damaged, deteriorated, have some signs of wear or have lost some of their properties through time making them weaker. It is important that when the building is being assessed to find potential reusable elements, the elements are looked at carefully to establish if they are still in a good enough quality and so if they could be reused in a different design or if this is the end of their lifecycle. The likely useful life remaining has to be evaluated to make sure that the elements will not have to be replaced too soon after their new implementation.

The condition of the element has to be assessed before the removal but also after. The quality of a material also depends on how it has been manipulated during the dismantling phase which should try to keep it as intact as possible and not alter it. Moreover, better tools have to be invented to make sure that the elements are not too deteriorated through the way they are removed when they arrive at the bottom of the building.

The investigation of the material for damages can sometimes easily be seen through carefully looking at the component. Some easily recognizable signs of deterioration are the rotting of the wood, obvious cracks in the bricks, water damage, signs of corrosion for metallic elements and so on. In other cases, to demonstrate their performance, some building components have to be carefully tested after their removal to make sure they still have the proper mechanical properties to be reused in the same way as before. This is often done for structural elements to make sure it is safe to use them again. Some of these damages do not mean that the elements can not be reused but it can have an impact on the quality of the element. A refurbishment of the elements can be undertaken to improve its performance. For example corrosion, rot and infestation can be treated.

Figure 29. Photography of a damages brick wall

The lack of technical documentation

The problem encountered with the building components which have been recovered from buildings is that - unlike brand new materials - they are rarely accompanied with a technical documentation or a guarantee. However « the requalification of the technical characteristics of building materials that have lived (and still are in good condition) is necessary to guarantee a level of performance to the building owner »[1]. The elements themselves need to meet standards and requirements to be able to be reused in the same way as before and if they are not conform; this can be a barrier to give them a new implementation. For now the certification of materials « varies depending on material and location but often there is a bias against structural use of old materials. Even there is a mechanism in place to regrade old material, some engineers are hesitant to take on the liability »[2]. People are sceptical about using elements which have already been used as they are seen as less reliable and might present a greater danger in new project. People are not willing to take risks.

The different criteria that can be established to value the performance of construction products vary depending on the elements and the envisaged use. Some examples of these criteria are for instance the mechanical forces of the element, the density,

1 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.169, translation by Charlotte Astaes

2 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p.44

and the rate of discolouration. Explaining the technical performance of a building component is important but methods and tests to certify the possible reuse of resources are not yet, for the time being, well established making it more difficult to place them on the market and find potential buyers.

Using salvaged elements in less demanding applications

If some elements have lost some of their properties but are still in a good condition, they can still be reused. If they do not meet the standards required to be used as before, maybe they can also be used differently, having a new use. This new use of the building component has to be taken into account because depending on that, some architectural applications pose fewer requirement than other making it perhaps easier to use a damaged element. For example, a finishing material must not achieve the same performance as a structural element. This can also be called 'cascading use'[3]. In this concept, it is well assumed that after some time, the elements have to be replaced because they wear and some undergo transformations or degradations, making it impossible to use the elements in the same way as before. Instead of going directly into the wastestream, this process is slowed down and the element only goes to waste when it is completely degraded. The residual qualities of an element are exploited as much as possible. This is done by using the elements in applications that are less demanding than the ones they have been initially designed for, and this can happen more than one time, until the element is totally deteriorated. In the document *Objectif réemploi*[4], they give some examples, such as used train rails reworked on secondary railway tracks; roofing slates reused as interior finishes, structural elements reused for non-structural purposes, etc. Some of these 'cascading uses' are more obvious than others as they require a more innovative and imaginative mind.

3 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.33, translation by Charlotte Astaes

4 Michaël Ghyoot, *Objectif réemploi: pistes d'action pour développer le secteur du réemploi des éléments de construction en région de Bruxelles-Capitale*, août 2017, p.43, translation by Charlotte Astaes

Future solutions

In the future, it is important that the components can maintain their mechanical properties as long as possible. They should be designed in a way in which the number of times they can be reused is maximized. The more robust they are, the more likely it will be to reuse them again and again.

To enable future reuse or recycling of elements, another idea that has been brought up is the development of material passports; also known as resource passports. The passports would provide technical specifications about a product and they could then easily be passed on to future generations. The technical specifications would encompass details such as products quality, material properties, guidance for maintenance, information about the production (e.g. the manufacturer and the location and time it was made), the lifecycle of the element, how long it can be used and how it should be handled when being dismantled.

In the book *Resource salvation: the architecture of reuse*[5], it is explained that the information could be tagged or attached to the element in a variety of ways by using, among others, QR codes, bar codes, electronic chips or imprints into a material. But it could also be done in a physical way by tagging or marking the material directly such as Romans were doing when they stamped their bricks to indicate the production site or brick maker. Others have suggested to store these kind of informations directly in the building information modelling (BIM) that could be accessed when needed, having a clear information about the properties of a component would make it easier to recertify and reuse it.

5 Mark Gorgolewski, *Resource salvation: the architecture of reuse*, John Wiley & Sons Ltd., 2018, p.55-56

FRATELLINI CIRCUS SCHOOL

Atelier Construire

2003

5000 m²

Saint-Denis / France

Circus school

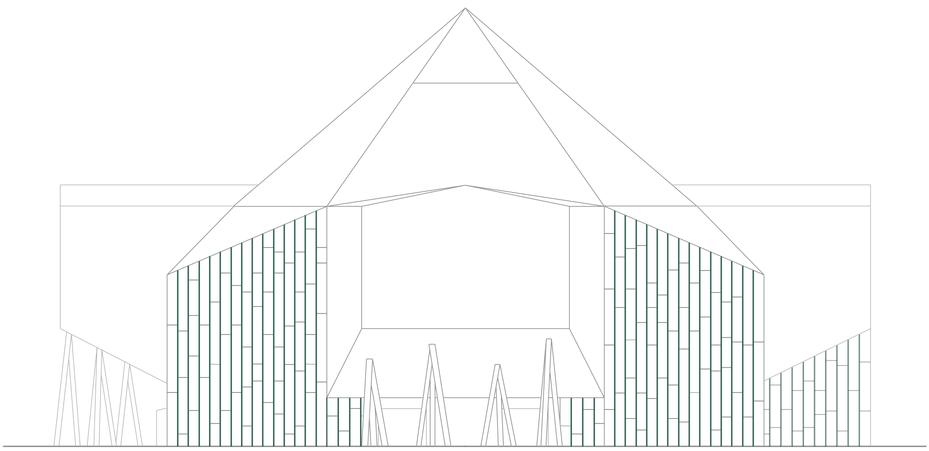

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Figure 30. Elevation drawing of the project the Fratellini Academy

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Figure 31. Photography of the metal sheets on the façade of the Fratellini circus school

FRATELLINI CIRCUS SCHOOL

Atelier Construire

Presentation of the office Consturire and the project

The office Construire (Paris) was founded by architect Patrick Bouchain and a few other collaborators. His work mainly focuses on the performing arts and he has transformed many industrial sites into thriving cultural spaces. He develops construction sites that are open to the public because he sees this as an opportunity for everyone to learn and he always tries to create connections between users, the designers and the workers on site. Besides, he keeps reconsidering norms and regulations.

The architects Patrick Bouchain and Loïc Julienne, from the office Construire, were contacted to redesign the art and circus school for the Fratellini Academy. The site hosting the Fratellini circus school is an old industrial site in Saint-Denis (a suburb of Paris). The project is an aggregation of different buildings. The site contained a wooden shed that was used as the academy's foyer, open to students and the public, where the classrooms, library and administration are. The other entities are arranged in the manner of a camp around the warehouse, without any general composition where we can find studios for rehearsals and training, a physical preparation centre, changing rooms, and workshops. The performing hall, a wooden star-shaped tent of 29 meters high is the main building and can host 1600 people. The project was built quickly and within a limited budget. Because of this, they tried to use rough and recycled materials as much as possible. In search of a cheaper cladding for the main building of the Academy, the architects wanted to recover corrugated sheets.

The search for metal sheets

They started a search to find metal sheets and when looking for old stocks to be reused, they asked the waterproofing contractor if he did not have any used corrugated metal sheets laying around and he answered: « le centre commercial de Disney vient de nous refuser toutes les tôles ondulées bronze, argent et or. On ne sait pas quoi en faire »[6] (Disney's shopping mall just refused us all bronze, silver and gold corrugated sheets. We don't know what to do with it). So the metal sheets used for the cladding of the building came from the Disneyland site where they were rejected. The project owner refused them once they were already installed because they were not all exactly the same colour.

Because they were not conform to the specifications given by Disney, the sheets risked falling in the waste stream while they were new and had not been used before; only placed in another project and dismantled directly afterwards. The person who owned the sheets did not have much choice, he did not have any prospect to implement them or reselling them. He could store them and wait until someone wanted to use them but for this you need to have enough space to store them or be able to dispose of them through the wastesteam.

Existing holes on the sheets present some implementation difficulties

Since the sheets were drilled during their initial implementation, their reuse was not that easy. The sheets were drilled accordingly to the layout plan for the building they were originally ordered for. The structure of the Fratellini is completely different, so the sheets could not be redrilled the same way and because of that, the existing holes on the panel could pose sealing problems. The sealing contractor told Patrick Bouchain that he could not install the sheets because they had holes.

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6 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.278

Superposition of the metal sheets to hide the holes

Despite the problem linked to the holes in the sheets, the architects still decided to buy them to use them in their project. They purchased these panels for almost ten times cheaper than the original price, making considerable savings on the budget. Initially, Patrick Bouchain was not sure on how to use the sheets but then he remembered how it is done in slums and he told to Julien Choppin and Nicola Delon that « in all slums, the sheets are assembled by overlapping them, to hide the holes »[7]. The same solution was then adopted where the sheets were superposed and placed in a way that would make sure the holes from the sheet under them were totally covered ensuring a continuity and to make sure that no water could penetrate. Because of that, the architect had to sign a discharge so that the sealing specialist can dismiss himself from any responsibility if any water damage happens because of how the elements are assembled. To differentiate the sheets and help with the corrosion happening on the slice where they were cut, they were soaked in a 10 cm black paint bath before being placed. The result of the facade is a random patchwork.

7 *Ibidem*, p.279, translation by Charlotte Astaes

Figure 32. Photography by Michel Denancé,
Fratellini circus school

BUILDING REGULATIONS

CHANGES IN STANDARDS AND NORMS CAN MAKE IT HARDER TO REUSE.

Some external factors can have an impact on the possibility of reusing some building components. Standards in the construction industry have been evolving through the years and changes in building regulations can suddenly disqualify or make it more complicated to reuse some elements that are still in a good condition. These changes can come from technical questions, for example changing some rules on the way of building and assembling things. They can also occur for legal questions, for example to make buildings safer or more energy efficient. All of these can break the process of reuse of components in future projects.

The building industry: a very controlled environment

The building industry is a very regulated and standardized environment and regulations do frame the act of building. It is particularly hard to reuse elements that already have been used in other projects. Many materials that have been installed in buildings ten, or twenty years ago have become unsuitable for new buildings because of the changes in the requirements. For example, Frédéric Anquetil explains in the book Matière grise[1] that since 2012, CE (abbreviation for European Conformity) marking, meaning that the element is authorized by law to be put on the market, of structural timber has become mandatory and as a result wood that has been recovered but which hasn't been requalified according to the CE marking is systematically refused on construction sites. The elements could be in perfect state but they are rejected because

1 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.169

there do not comply with the law. Today, all the elements used in construction have to proof their conformity and follow the norms. It is very hard to do anything that derives from the traditional way of doing things. When contractors, builders or architects try any deviation from the standards, they have to provide insurance but most people do not want to do take any risks. The reuse of elements needs a development of unconventional methods but because the way we built is so regulated by norms, it is very difficult to attempt anything.

Finding ways to overcome the problems linked to strict or outdated regulations

Architects have to face or get around the problem of standards. If nothing is done, the implementation of reused materials in buildings will only happen very rarely. Good examples through time where the reuse of materials has taken place could maybe help regulations to change in a way where reused elements could be more often implemented in projects and maybe one day would become the norm itself.

In the meantime some architects try to find tricks to be able to reuse some elements and get around the regulations. One example is the French scenographer Patrick Bouchain in the project 'Le Lieu Unique'. He used metal cans for the acoustic ceiling. These were thrown away because they were damaged, deformed and polluted as they contained acid. They were imported from Mali in Africa to Nantes under the status of 'work of art' in order to get around the customs regulations on polluted materials. Furthermore, he used African bogolans - a handmade cotton fabric painted with earth and dyed with fermented mud by Malian women. The firm bought two hundred and fifty of them. They were not conform with the fire standards but Patrick Bouchain decided to glue the fabrics onto the wall, like it is normally done with wallpaper that is also flammable. The fire brigade and the control office could only approve and the bogolans were installed with fish glue. This example shows well that with some innovative ways of thinking, it is possible to get around some of the enforced regulations that exist nowadays.

EUROPA

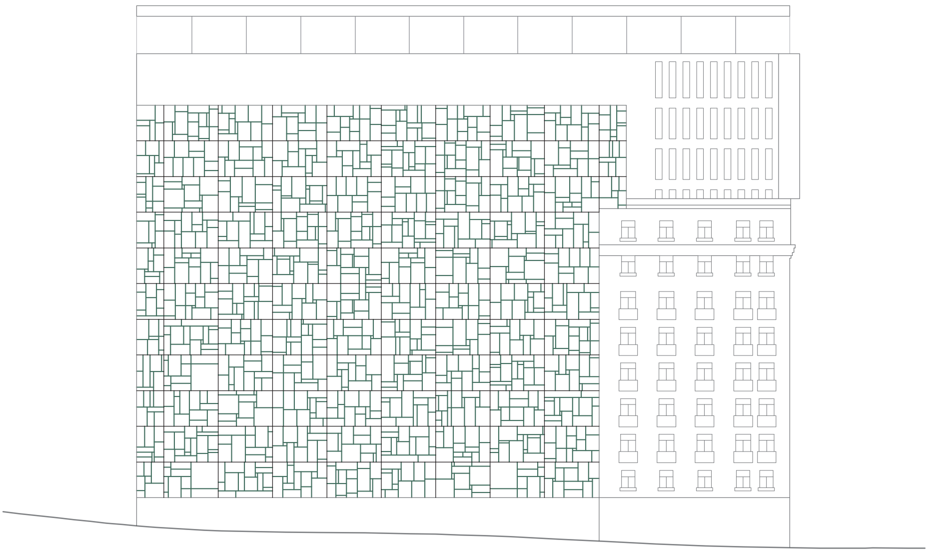
Philippe Samyn and Partners

2008-2015

53 815 m²

Brussels / Belgium

Offices



SCALE 1:750

Figure 33. Elevation drawing of the project Europa

Opposite page

Figure 34. Photography by Thierry Henrard, the Europa building from the exterior

EUROPA

Philippe Samyn and Partners

Presentation of the office and the project

The project was designed by Philippe Samyn and Partners - a Belgian architecture bureau which always tries to approach projects with a new perspective. Back in 2004, they took part and won a competition launched by the Council of the European Union. The organisation needed new spaces. Through the making of this new building, the European Council wanted to show its dedication to sustainable development.

The main idea of the project was to transfer the Council of the European Union from the Justus Lipsius building becoming too small somewhere else. For this, the Belgian State offered to renovate and adapt the a building called the 'Residence Palace' to meet the future needs of the European Council. This construction used to be a residential complex from the 1920s and it was later on renovated into government offices. However; it needed more surface to be able to have conference rooms to accommodate sessions between all the countries of the European Union, press rooms, offices and parking.

The main intention was to extend the new building on the north-east side to transform the current L-shaped building into a cube. This has been done by implementing two new transparent façades that create an atrium inside. These new façades, made from windows, provide an acoustic buffer against traffic noise and it also provides a first thermal insulation for the interior space of the atrium.

The replacement of single glazed windows

Today, it is seen as necessary that buildings are as energy efficient as possible and regulations have been put into place through the years to make sure that a reduction of energy is happening. Because of that, many assemblies (components put into place before the current energy friendly regulations) have become outdated and do not longer perform well enough according to these standards. Many of these elements end up in landfills. Such is the case for examples for single glazed windows. All the windows in Europe, with the evolution of thermal regulations in buildings, have to be upgraded form single glazing to double glazing having as a consequence that many old windows are thrown away after they have been replaced. For example, more than 8 million windows have been replaced on the French territory only in 2010 [2]. The new headquarters of the European Union try to offer an option where old windows are integrated within the new facade.

Reusing old windows into a double skin façade

The design of Philippe Samyn introduces a new double-skin facade where the outer skin is composed of old oak windows. This type of single glazed window has often been used in various European countries. These elements are not suited anymore to be used as windows and have thus found a new use and have been installed on the outer layer of the double skin facade. Behind stands a higher efficiency glazing.

A Belgium construction company called Antiekbouw, which recovers and collects historical windows already had a large collection in stock of oak windows. The founder of the company Karl Staelens helped finding even more windows and these primarily came from the following countries: France, Germany, the Netherlands, Italy and Spain. It was not known when the windows were produced or when they were dismantled from their original building but they were all

2 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.200

checked for quality to make sure that the products were in a good enough state to be reused.

Once the elements were collected and approved, a method had to be found to hold all of them together. As this had not been done before, some research and tests had to be done to find an innovative way of doing this. Once established, the new methods could also be used in other projects in similar ways way or they could be further improved. A module was established with a structural steel framework that would hold the windows together. The various windows were placed into a coherent patchwork into this frame once they had been cleaned, sanded and given a finish coating to unite their tones visually as well as protecting them against moisture. Finally, this project included around 3000 old oak windows.

A creative solution

This project offers an answer to the problem of elements that can not be reused because they are not conform to current industry standards. Single glazed windows are often seen as unsuitable for reuse due to the use of modern glazing that perform better but this example shows that they can still be used into new designs as underlined in the book *Resource salvation*: the architecture of reuse « Their use in a double-skin façade, where their low thermal performance can be compensated for by the second glass layer, is a creative use of this valuable resource that can be repeated elsewhere »[3]. Oak is a very durable material that can last for many years and it would be a shame to see these elements finish into the wastestream before the end of their lifecycle.

3 Mark Gorgolewski, *Resource salvation: the architecture of reuse,* John Wiley & Sons Ltd., 2018, p.133

Figure 35. Photography by Philippe Samyn and
Partners, construction of one module

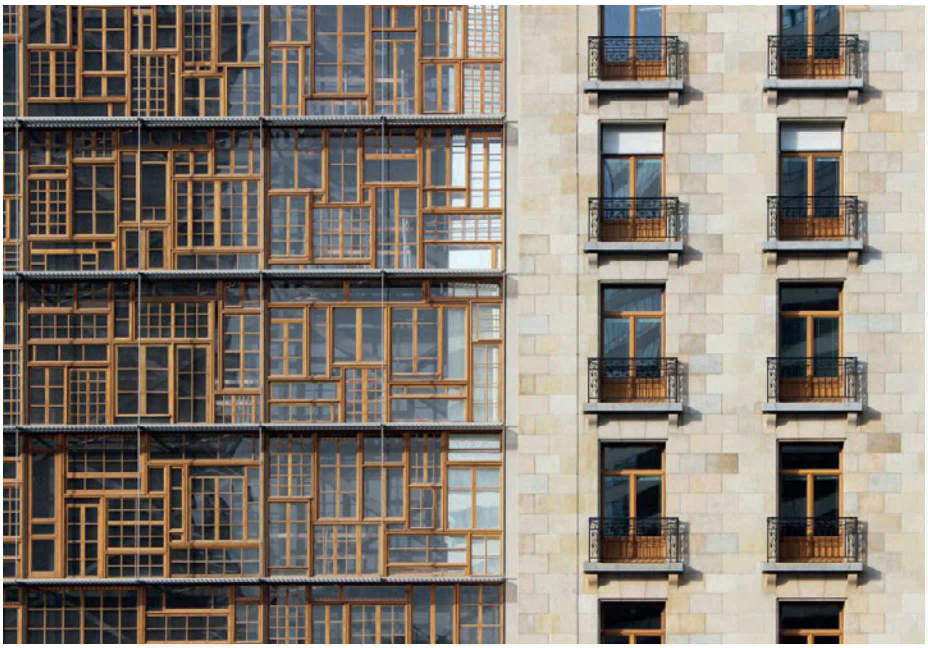


Figure 36. Photography by Quentin Olbrechts,
Detail of the connection between old and new

APPRECIATION OF RECOVERED MATERIALS

THE ELEMENTS HAVE TO BE APPROVED BY THE PUBLIC.

Small damages, deterioration and signs of wear on the element has an impact on the condition of the elements. In some cases, it can be appreciated and has a positive impact. This happens mostly in the cases of architectural antiquities. But it can also have an negative impact and the element can be seen as weak, or impaired. During the dismantling process, workers should be careful to not alter the aesthetic properties of the elements because « many people appreciate the harmonious wear of an old blue stone. They are much rarer to find satisfying a large line related to an unfortunate manipulation during disassembly »[1].

Elements can be reused for their emotional value and not only for economical or ecological reasons. Some buildings, because of their origin and the time they have been built carry a historical value which can be much appreciated by the population as they are seen as a part of the patrimony and a link between the different generations. The components of these kind of constructions are more easily used again.

For other buildings, if the elements are not seen as aesthetically pleasing, it will be harder to sell them to potential buyers and so to reuse them. The appreciation, meaning the reaction of the public to the elements, is very relevant in the potential reuse of an element.

1 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.99, translation by Charlotte Astaes

Problems linked to preconceived and often negative views on the act of reusing old materials within new structures

One relevant problem is that reuse is often seen as the recovery of old things. In some cases, the old element can have some value but in most cases, it is just seen as waste, something unwanted and without use.

The elements might have lost their aesthetic value because they now wear negative connotations, by form or materiality of being made in a specific era that is not in trend anymore. If the element is not pleasing to the eye, it will not meet any demand and its chances of being reused drops significantly. Nevertheless, taste is something very subjective and it is rarely fixed. It is possible that some of the elements eventually come back in style.

Besides, recovered construction elements sometimes carry a negative significance among the general public and also to some professionals. Recovering and reusing elements is often perceived as something restricted to the poor and the underprivileged who need these to built their homes in slums. It can also be associated with craft work where improvisation, testing and inventing is key. The general impression is one of marginality. However, this is starting to change as the number of projects using reused building components is growing.

The aesthetic value of buildings and their components

It can be difficult for people to reuse salvaged materials when they do not appreciate them. It usually works better for buildings that are seen as having some value. The value can come from an appreciation of the wear of the materials, such as architectural antiquities. It can also come from the cultural value of the building, making the element appear as a link between different generations. And finally it can happen for the elements which are associated with beauty and aesthetic properties.

Architectural antiquities are more easily reused as old objects which have been crafted artisanally contrast with elements made for mechanical production. Handmade elements are unique. They are all slightly different whereas machines make everything look exactly the same, and without any flaws. The appreciation of the antique elements comes with time. Their surfaces can be a bit degraded and might carry signs of wear but these vouch for ancientness and as Aloïs Riegl says, quoted in the book *Déconstruction et réemploi* by Rotor, they « testify to the work of dissolution, slow but certain, relentless, imperative and therefore irresistible, that nature achieves »[2]. The natural weathering becomes a real source of aesthetic satisfaction and shows a form of seniority appreciated by many. To recover architectural antiques, some dealers take the trouble to recover them and preserve them despite all the technical obstacles that can exist only because of their extensive appreciation. The interest for these elements has started after the Second World War when businesses started to emerge as a way to protect elements from destructive demolitions. The enthusiasm for these has not yet disappeared and the existing market is pretty stable in Europe.

Buildings that have been standing for centuries have a patrimonial value. In most cases, people are attached do these kind of buildings and do not like to see them get thorned down. Their value comes from the materials used which preserves traces of wear from the historical background of the building itself but also from the assemblies and work done through time to preserve it in its current state. The elements of these types of buildings are more easily reused because they are carriers of our common history and collective memory. Reuse is thus a way to preserve the cultural dimensions of these buildings. Actually, reusing elements from old buildings is one of the most well-known examples of reuse and happens pretty often, because monuments are the focus of our attention and preservation. When it is not possible to keep and conserve the building in its whole, the alternative is to reuse parts or building components that can still give something to the next generations and not lose all of the information stored during the construction.

The concept of beauty is seen as pertinent in this case, underlined in the following idea: « if a building is considered beautiful, it tends to stand longer, thereby saving precious resources »[3]. This

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2 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction,* Presses polytechniques et universitaires romandes, 2018, p.45, translation by Charlotte Astaes

3 Rotor, *Behind the green door: a critical look at sustainable architecture through 600 objects*, Oslo Architecture Triennale, April 2014, p.165

is also applicable to components; they have to be aesthetically appreciated too, so that as many people as possible make sure they are reused. Through time and concrete architectural examples both appreciated by the public and seen as physically attractive, people will get used to seeing buildings where elements have been reused. As a consequence, they will be more open to the idea that this could be done and professionals will adapt to the rising demand.

KLOSTERGARTEN LEHEL

Hild und K Architeckten

2007-2009

3900 m²

Munich / Germany

Residential complex

SCALE 1:300

Opposite page
Figure 38. Photography by Michael Heinrich, façade of the Klostergarten Lehel

Figure 37. Elevation drawing of the Klostergarten Lehel

KLOSTERGARTEN LEHEL

Hild und K Architeckten

Presentation of the project

In 2006, Hild und K Architekten were commissioned, from the Bayerische Hausbau, to built a new building consisting of thirty-two apartments with a total floor space of 3900 square meters. It would be erected on the former refectory and student wing of the St Anna's monastery, that was built in 1910. The community of the Franciscan monks had shrunken from 120 to 15 monks. The cloister, of a total surface of 6000 square meters, became too big and the monks needed less space to live in. Because of that, they decided to sell almost two third of the cloister surface.

For this project, the architects did not want to split the complex distinctively between what was the old part and what was the new construction. It was their goal to ensure harmony between the two.

An impossible conversion of the existing building

Different problems occurred through the project. The investor insisted on the building to be demolished because he thought the redevelopment of the existing building into its new residential use would be too expensive. That came from the small cell structure of the monastery that was unsuitable to be converted into living spaces. If the building was preserved and altered, the client would have paid half as much to the monks. The monks would then have had to move out and go somewhere else leaving the whole cloister empty. Furthermore, the monastery building was standing under historical preservation and the building conservation authorities were against the demolition of the construction.

The architects had to find a way to make everyone come to terms and they did so with their concept of 'oldnew' that persuaded the conservation authority to allow the demolition.

Figure 39. Photography by Hild und K Architekten, original building before demolition

The preservation of five original windows

Finally, the building was dismantled but some elements were preserved to be reused in the new project. That was the case for the original neo-Romanesque window arches. The five elements were reinstalled onto the façade of the new building facing the monastery's garden. This allowed a continuity with the still standing part of the old building. Even if the different nature between the building components is clearly evident, the old and the new form a new whole. Originally, all the windows were standing on the ground floor but now they have been set up in a way to form a diagonal.

The arched windows were almost five meters high and they presented some challenges in the design of the organisation of the inside spaces. To solve the irregularity problem of the interior, the architects designed split-level units and some halls go up to 4,5 meters high. So the use of these windows led to new spatial qualities, with an interaction between high and low spaces.

This type of reuse was more an emotional one, to make sure that part of the historical building would be preserved, than a reuse done for economical or ecological reasons. As said by Andreas Hild: « The hope is to be able, so to speak, to transfer some of the magic to the new »[4].

4 Muck Petzet and Florian Heilmeyer, *Reduce, Reuse, Recycle: architecture as resource*, conversation with Andreas Hild, Hatje Cantz Verlag, 2012 , p.178

ECONOMICAL VALUE

COSTS INVOLVED IN THE DECONSTRUCTION AND RECONDITIONING OF MATERIALS

Every step in reuse involves a certain cost that is then compared to how things are done nowadays. If the new way is not seen as economically interesting and is less expensive than the traditional way, reuse will not be seen as a good option. If the client can not see how he will benefit from using recovered elements, it will be harder to convince him to use this approach. Knowing the demand for these kind of materials before starting deconstruction is necessary because it permits to avoid investments at a loss. This means that it is not necessary to provide the efforts of dismantling if a buyer is never found for the items.

Some studies consider that reuse is more expensive but other studies show that it can be economically interesting and that savings can be achieved through deconstruction in comparison to demolition. But it depends on a number of different factors: the cost of the deconstruction process versus demolition, the reconditioning of the elements and their price once on the market.

The price of deconstruction versus the price of demolition

Deconstruction implies careful removal methods as the elements are removed one by one to make sure that they can be reused in other projects. The removal is done by light mechanical means or by hand. This is often more labour-intensive then regular demolition, it also has an impact on the time and all of this has an impact on costs. Deconstruction costs are nowadays pretty high because of the inexperienced workers with this type of work and also from the lack of appropriate equipment. Human labour is pretty expensive and this prevents the recovery of materials that are considered as having a low value. In the book *Déconstruction et* *réemploi*[1], they explain that if a closer look is taken to the value of building components. It appears that in many cases, the finishing elements represent a substantial part of the investment. An example is given of a floor detail. It is made of a concrete structure, various membranes, a layer of sound insulation and on top a solid wood floor. This last element represent on its own 20 percent of the total price of the detail. These last layers are also normally more accessible than other elements and can be easily retrieved if not fixed irreversibly. This is why the finishing components are the most recovered and found on the market.

Furthermore, the layout of the site and the installations brought there depends on the number of people involved and the type of dismantling. In case of selective deconstruction, as more people are involved and the elements have to be carefully brought to the ground, the cost associated with these accommodations may be higher. If the site is small, it will be less easy for the workers to operate and it will be harder to store materials on the site.

The costs involved in demolition or deconstruction also include transportation and disposal. In some cases, transportation can exceed the gains made from the recovery. For demolition, there is the cost to bring the elements to waste management sites, such as recycling platforms, sorting centres or landfills. It is necessary to pay to recycle or dispose of the materials and the prices depend on the type of material, on the size and on the weight. Landfills have a trend of rising prices to encourage people to bring the materials to recycling facilities. For deconstruction, the cost of transportation can be close to zero if the elements are reused on site, otherwise it is linked to the distance of the place where the elements are stored, but it should always try to be local. For now, demolition is still perceived as the most cost-effective option, despite the increasing price of landfills.

Potential additional costs due to reconditioning or refurbishment

Once the elements have been removed and sorted, there are cost involved in the validation of their performance to documentate

1 Rotor, Déconstruction et réemploi: *Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.97-98, translation by Charlotte Astaes

them and also in their reconditioning, to prepare them for being reused.

To validate the quality, the cost can be close to zero if someone has enough knowledge and expertise on site to approve the element. Cost can rise rapidly if the element needs to be tested in a laboratory to make sure it has not lost its mechanical properties. These tests are in most cases very expensive.

Most of the elements need to be reconditioned and restored into a good condition before they can be reused in another project. This consists of checking, cleaning, repairing, harmonizing and packaging the components. The different steps ask for a certain amount of time and work depending on how deteriorated the items are. But generally speaking, it requires a larger workforce than in the more traditional waste management facilities. The refurbishment can happen on site if the damages are superficial. If not refurbishment happens in architectural salvage yards or the elements can be returned to specialists firms or the original manufacturer. This step always depend on whether the element is seen as valuable enough to make reconditioning possible.

All of these factors affect the selling price of the elements by, in most cases, increasing the cost. It can make them a disadvantageous option compared to their new equivalent once they are put back on the market. If the price is too close to the price of the same component but new, this material will in most cases not be interesting for potential buyers. New building components are sold to a very low price.

It does happen that in some cases, elements are economically interesting and their recovery with the idea of being reused has greater chance to happen. If some elements are in demand on the market and the product is expensive, it can be interesting to have a less expensive alternative. For example exotic woods, that were extensively used in architecture in the first half of the 20th century are now endangered species. There selling price has increased significantly in the last years. In this case reuse is a relevant and interesting alternative as it enables to find these products for a much lesser price. Elements can also reach a high price if they have a heritage value and are seen as architectural antiquities and it is not possible to find the same product on today's market.

Possible solutions to reduce costs

The elements commonly reused are those that have a good ratio between the dismantling and treatment costs and their resale price. Some factors have a big impact on the price of the elements but if the impact of the cost of labour was revised downwards, if appropriate tools were developed making the time of deconstruction shorter, then the range of elements being reused could probably increase for much lesser costs. This sector needs some time to improve its structure but with progress, costs will probably decrease.

It is also interesting to note that the recovered building components offer interesting advantages. They have a low environmental impact, cultural dimensions, and they are products of a local economy. These are all criteria that should be valued together with the selling price.

LA FABRIQUE DU CLOS

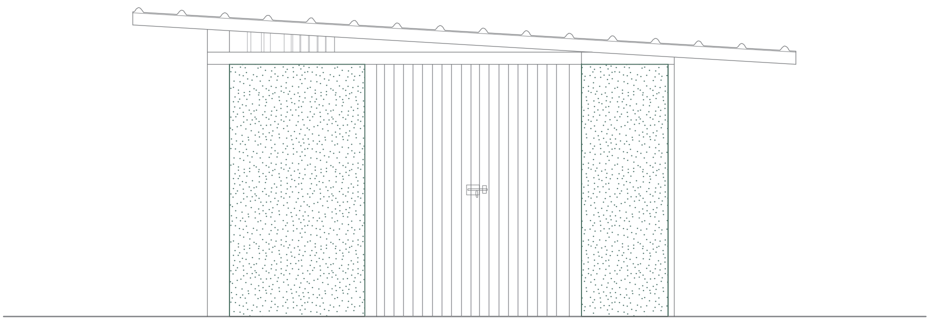
Bellastock

2016

18 m^2

Stains / France

Shelter



SCALE 1:75

Opposite page

Figure 41. Photography by Clément Guillaume, La Fabrique du Clos

Figure 40. Elevation drawing of the Fabrique du Clos

LA FABRIQUE DU CLOS

Bellastock

Presentation of the project

For this project, French architecture firm Bellastock had to oversee the demolition of several building towers and it provided its expertise on the possibilities to reuse the materials. They proposed different prototypes: a path made from eight centimetres thick concrete pieces, dry stone walls to create seating and a small outside structure made from concrete.

This project tried to involve the inhabitants of the district and it was carried out by four craftsmen from Bellastock, five employees of the Clos-Saint-Lazare district and eight interns in landscape architecture. This common work allowed a transmission of skills.

We will take a closer look at the 18 square meters pavilion. For this small project, 15 centimetres thick concrete walls were recovered from a social housing building built in the 1960s. 45 square meters were then assembled as non load-bearing walls in order to create an external bicycle garage and garbage room. The space is ventilated but not heated. This proposal was financially analysed in 2016 by Bellastock[2]. The reuse was compared to the constructive process of using solid bricks or cinder blocks for the structure.

Specificities of the deconstruction process

For the dismantling of the elements, a saw had to be used to precisely delimit the materials and separate them from the building's load-bearing structure. The elements were then removed using a hydraulic clamp.

2 Bellastock, *Repar#2: le réemploi, passerelle entre architecture et industrie*, colloque de restitution, avril 2018, p.189-193

The elements were conditioned and stored on the site where they would be reused. The ground was located only 400 meters away from the deconstruction site. If the elements would not have been reused, they would have been disposed off, but luckily this place was only 20 kilometres away. This way, significant gains are made in transport because of the proximity of the new construction site.

Once dismantled, the components are required to be transformed and adapted to the needs of the new project. The implementation in the new construction is different in comparison of the previous use. This necessitated the use of a saw to adapt the collected materials. A telescopic forklift was used to handle the heavy elements. The implementation required to use of a self-propelled crawler crane and a additional treatment was also necessary to treat the exposed concrete armatures to form a protective coating on the surface to make it less susceptible to corrosion. This is done by passivation.

Figure 42. Photography by Alexis Leclercq, pieces of slabs recovered from the demolition are sawn on site

Economical impact: Financial analysis by Bellastock

In this prototype, some material was lost during the handling and transformation. Around 79 percent of the material could finally be reused. 10 percent was lost during the dismantling and another 10 percent during the preparation of the element to be reused.

There is also an impact on the number of total days needed for the deconstruction. For the recovered concrete, eleven days were needed from the start of deconstruction to the delivery of the material ready to be reused. The various actions related to the reuse have been mainly carried out by professional companies that had the specific skills.

The time related to implementation, superior to traditional construction and the time and technical means necessary for reconstruction, like the use of specific machines, had an impact on the total costs.

An initial analysis related to the experiment showed that the total expenses related to reuse was about 7 percent higher than to a construction where solid bricks would have be used and it would be almost twice as high as the cost of a construction with cinder blocks. These costs are mainly related to the operations carried out during dismantling where saws were involved and the time given to the preparation of the elements.

Possible modifications in future projects

The calculated costs come from an experiment. They could be significantly reduced if the different steps are improved and a methodology that could be replicated would be implemented. The improvements would have an impact on the financial balance sheet.

For example, the process of collecting the materials could be modified to eliminate the costs of pre-sawing. The time spent on modifying the parts and the use of specific technical means could be reduced. If the modifications are implemented, Bellastock estimates that in this optimized scenario, a 30 percent reduction in costs of the reused structure is possible[3] 3. This scenario could even be further improved. With these new calculations, the construction becomes economically beneficial for the client compared to a similar brick structure but would still be a bit more expensive than a cinder block structure.

This experiment shows that today reuse is in some cases more expensive than the traditional way of doing things but presents many potential improvements. In the future, by improving and optimizing the deconstruction processus, the tools used and the skills of workers, it would be possible to make reuse economically beneficial.

Coût des étapes supplémentaires par m²	Prix
Diagnostique réemploi	1,9€
Abattage sélectif	8,8€
Transport vers site d'utilisation	0,9€
Transformation / préparation de la matière	160,2€
Intégration dans le projet architectural	57,6€
TOTAL procédé constructif en « réemploi »	**255,6€**

HYPOTHÈSE BRIQUES PLEINES

Coût des étapes supplémentaires par m²	Prix
Traitements des matériaux (évacuation de la matière après démolition)	28,5€
Achat de matériaux neufs (yc transpor)	225,0€
Mise en œuvre	80,0€
TOTAL procédé constructif classique	**333,5€**
RÉSULTATS - Économie générée par le réemploi (en € / m²)	**-77,9€**

HYPOTHÈSE PARPAINGS

Coût des étapes évitées par m²	Prix
Traitements des matériaux (évacuation de la matière après démolition)	28,5€
Achat de matériaux neufs (yc transport)	95,0€
Mise en œuvre	40,0€
TOTAL procédé constructif classique	**163,5€**
	92,1€

Figure 43. Bellastock, Comparative tables of the optimized financial analysis of the concrete pavilion for reuse and the hypothetical prices of a solid brick or block shelter

3 *Ibidem*, p.191

III

A METHODOLOGY

This chapter wants to offer a possible methodology to evaluate the building and the components for their potential reuse and make a personal inventory of the elements that can be reused. This is a test of a possible approach that could be put into practice. This methodology is separated into two parts. The first part is a box, called the sustainable toolbox with all the questions that one should ask him or herself when confronted to a building that is going to be demolished in order to determine what can be reused. It is separated into three subparts following the zero waste hierarchy. The second part of the methodology suggests a step by step procedure to make an inventory of the identified reusable components in a building.

A NEW ROLE IN ARCHITECTURE TO ASSESS BUILDINGS BEFORE THEY ARE DEMOLISHED

In the previous chapter, it was discussed that various criteria have an impact on the assessment of the probability of an element to be reused in a new project. This evaluation can be completely different from one project to another, depending on when it was built, its location, the materials used and many more factors. There is no scientific formula or methodology that gives an answer on how to do this that works for all the buildings. However as previously outlined, there are new professional roles that can be created in the sector of building deconstruction. One of them consists in identifying the potentially reusable elements in buildings before demolition. Indeed, someone should go to the building site and assess if the elements can be dismantled without too many damages in order to be used somewhere else. All these building components and materials could then be put into one document, adding other informations. As such, an inventory would be established and it would help to create a usable stock of materials. The more information we have about an element, the more its likelihood to be reused is increased. This type of work would also help to develop the reuse sector and make sure that more elements find a second use in the future.

In the book *Déconstruction et réemploi* [1], this new professional role is compared to the job of a prospector. It consists of identifying the location of exploitable natural resources, like minerals, fossils and metals, in a territory. Experts add that the essential abilities to do this type of work are good observation and deduction skills and that these are also important in the identification of salvageable materials. This person also needs to be versatile and be able to communicate and work with many different types of people to find all the relevant informations about the building and building

1 Rotor, *Déconstruction et réemploi: Comment faire circuler les éléments de construction*, Presses polytechniques et universitaires romandes, 2018, p.101-102

components. Sometimes, finding specific types of information requires particular knowledge. For example, exchanges could be done either with historians to assess if some items have a patrimonial value, or with laboratories and test centres to analyse the quality of materials. Finally, professional contamination firms would have to be contacted to see if hazardous materials are present on site.

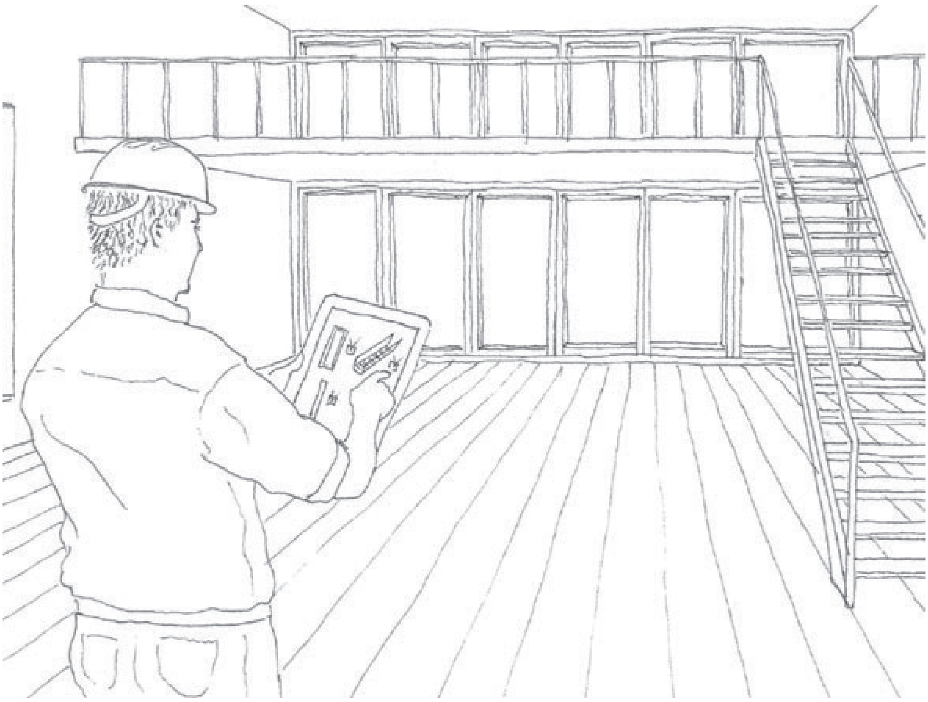


Figure 44. Illustration by Rotor, Pre-demolition diagnostic to identify reusable materials

THE SUSTAINABLE TOOLBOX

The first part of the methodology consists of a box, called the sustainable toolbox, which contains the questions that should be asked before a building is going to be demolished. These should help to identify the different options offered to us and to estimate if some form of reuse is possible.

The box is separated into three parts following the zero waste hierarchy, determining what would be the most sustainable option to the least sustainable one. The first degree is 'reduce': the whole building should be assessed to see if it possible to keep it as intact as possible and on the same location. If after reading all the questions, it has been evaluated as impossible to conserve the construction, we go to the second degree. This one would be 'reuse': the building components and materials should be assessed on their own and see if they can be reused in another project. The established questions for this step use the criteria outlined in the second chapter to bring up the points of attentions and the aspects that should carefully be looked at. Finally, the last degree is 'recycle': the elements that have not been assessed as being reusable can maybe be crushed and recycled. Also, it is possible that at the end, some items have been assessed as not being able to be recycled or reused. These will probably go to landfills or be incinerated but these steps have not been added in the box.

The questions can be found in the physical box that is accompanying this essay. The questions in the box can easily be modified. With time and real experiences, more questions could become relevant and others could become obsolete. These can then easily be added or removed from the box.

INVENTORY OF POTENTIALLY REUSABLE MATERIALS

The second part of the methodology is the inventory. This step mostly happens if the building can not be reused on site. If only minor changes occur on the building, then this is not essential. Sometimes, only the structure is kept, in this case the inventory could also be done for all the other materials and building components not needed in the new project. However, the inventory is necessary when the whole building is going to be deconstructed.

This inventory becomes a tool where all the information and data of the potentially reusable materials, found with the help of the sustainable toolbox, are put into one document. This inventory can be useful to architects, contractors or other market specialists, for example people that resale antiquities.

This document can then be used internally or be sent to exterior actors. Internally, the report can help in the design of new projects. The produced document can also be used externally. This means, it can be sent to potential buyers asking them if they would be interested to purchase some of the materials. This document could be sent to other architects, designers, salvage yards, deconstruction firms and others. This document could also help buyers to put more information on the existing market or for new platforms possible to find on the internet. Accurate information will help people to consider the reuse of recovered elements in the design of new projects. This inventory would also help to determine which kind of tools or techniques are needed to dismantle the elements.

The methodology to establish this inventory has been made with the help of a document put in place by Rotor[1]. The method is explained step by step starting from the essential parameters that have to be detailed. After that, a possible way on how the elements can be categorised to make the document more readable is explained.

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1 Rotor asbl, *Vade-mecum réemploi hors site*, Annexe 3: comment dresser un inventaire des matériaux potentiellement réutilisables, juin 2015

STEP 1

Create a new document. This can be done in Indesign, Excel or any other preferred program. All the necessary information and data will be put in the document. It would be interesting to create a layout that could be reused as a model for the next building's assessments.

STEP 2

The first informations that should be written down in the document should be some general facts about the building such as the address, date of construction, total surface, scheduled demolition date and so on.

STEP 3

Write down all the elements that were discovered in the process of the building evaluation as being potentially reusable and that have no use anymore in the current building. Each item should be clearly distinguished from the one before and the one coming afterwards. These should have some detailed information about them, explained in step 4. They should also be separated into different categories, explained in step 5.

STEP 4

For each defined item, answer the different parameters explained underneath. As many as possible parameters should be answered, because the more information there is on the items, the more likely they will be reused. However, if not all the data is found, it does not mean that the element can not be used again. Try to stay brief but relevant for each specification. The different parameters are:
- A title: give a short title that explains clearly what the building component or the material is.

- A description: give a short description, one or two sentences, explaining what the element is. If the element has any information about the brand it was made from, it can be added in the description. For example, if a radiator still has the name of its manufacturer.
- Materiality: explain from what the component is made of. For example, a window can be made from glass and wood or from glass and PVC plastic.
- Dimensions: take precise dimensions of the element. The surface can be added when considered relevant.
- Assemblage: describe how the element is fixed to another one. This will help with the choice of tools in the dismantling process.
- Location: describe where the element is situated in the building. It can help to evaluate the difficulty to recover the material, for example, if it is very high, more important exterior adaptations will be needed.
- Quantity: describe how many elements are there of the same. If this information is not clear, give an estimate.
- Mass: give the mass of one unit and the total mass of all the same items. The volume it represents can be added when relevant.
- Remarks: describe precisions on things on which attention should be given to, for example, default or damages present on the building component. Anything judged useful for the deconstruction that cannot go in the other parameters can be added here.
- Pictures or drawings: take a picture of the element that captures the environment in which it stands. Pictures of details can also be taken to show a defect, a particular feature or the fastening system. Drawings, like plans or sections can also be added to help locate the materials in the building for example. This helps to give rapid visual informations and to grab the reader’s attention.

STEP 5

The elements should be separated into different categories to help evaluate the nature of the items. Furthermore, it makes it easier to read and find quickly information in the document. The different categories could be:
- Equipments: tools or objects commonly used such as sanitary, lights, radiators. These are often easily dismantled.

- Interior finishes: materials used to cover the interior areas of walls, floors and ceilings such as tiles, marble, wood and paint.
- Technical elements: any building service, such as ducts, plumbing, elevators and ventilation shaft.
- Cultural elements: components that have a heritage value by their usury, materiality or origin.
- Non-structural elements: components supporting no load other than their own weight such as partition walls, windows and doors.
- Structural elements: all load bearing components of the building such as exterior structural walls, columns, foundations and the roof.

STEP 6

Once everything is ordered into one document, save it as a PDF file. The final document should be clear and appealing. It is finally ready to be send out to potential buyers if needed or it can be used internally.

CONCLUSION

Environmental issues like the depletion of natural resources and the accumulation of waste have been rising concerns for a while now. Yet, radical measures still need to be taken to keep the level of carbon dioxide in the atmosphere from increasing even more.

It appears that the construction sector has a large impact on these concerns and it must renew itself, finding unique sustainable approaches. Among the possible answers, one is the reuse of building materials. Although still in its infancy, the concept of reuse has been growing and it is starting to be promoted by pioneering architects and engineers. According to architects Julien Choppin and Nicola Delon, in their book *Matière Grise*, « the reuse of building materials is one of the tools for the transition to a less 'material devourer' architecture »[1]. This underlines the idea that reuse would allow for a general economy of materials.

Unfortunately, today less than 10 percent of the elements composing a building are recovered and used again. This is why I thought that it was essential to understand the obstacles surrounding reuse. But I found that the constraints relating to time, logistics, regulations, aesthetic and economy could easily be overcome through innovative techniques and imaginative thinking.

During the last few years, concrete examples have come to life and the methods implemented in these projects can be great sources of inspiration and they can also be reinterpreted depending on the situation people are confronted to. Moreover, to help people in the building industry to try and meticulously observe each building before demolition, a methodology has been put into place. The methodology wants to instore a more thoughtful way of examining constructions and make it possible to quickly find all the factors that

1 Julien Choppin et Nicola Delon, *Matière grise: matériaux/réemploi/architecture*, édition du pavillon de l'Arsenal, 2014, p.345, translation by Charlotte Astaes

should be considered during a building's evaluation for reuse. At this point, the methodology is a first draft which can be improved with other experiences in the hope that more materials can be reused in the future. This is only one way of how things can be done and new approaches will probably be developed in the next few years.

The reuse sector will hopefully take more importance and more experiments will be carried out. So far, examples of offices that have taken an interest in these questions are Rotor in Belgium, Bellastock in France and Lendager Group in Denmark. The general public also feel increasingly concerned by the threat to the environment and the planet, and we should wish for a future where architects, engineers and the people work together towards future sustainable solutions in the building industry but also for the common good. Research and knowledge does not stop to grow on this topic and maybe, in the future, reuse will start to be implemented in common practices.

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